CHAPTER 3

A Social Timing Model of Autism, Informed by Typical Development

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1 Introduction

The temporal structures of conversation are familiar examples of how timing is a critical element of human communication. Altering the temporal structures of conversation can have semantic implications and influence our sense of interrelatedness with the speaker. The anticipatory pause, for example, used on stage for comedic effect, uses timing to tease the audience, perhaps drawing out a double meaning that may have otherwise be missed. Similarly, in parent–infant play (in a game such as peek-a-boo) it is the temporal element that is the critical fun-factor in the game that delivers salience and amusement for the child.

Our media-filled social world also relies on timing in communication at both the macro- and micro-scale and deviation from the typical may result in failure of effective communication. Occasional audiovisual de-synchrony in broadcast and recorded media affords neurotypical individuals the experience of communication with unusual temporal constraints. Such de-synchronization increases cognitive workload and negatively impacts on feelings of interrelatedness.

Clinical experience of altered timing in the interactions of people with autism has led to hypotheses that focus on the role of timing in autism. To date, this field has been under-researched although there is general clinical consensus that forms of temporal impairment are common in autism. Whether, and to what degree, these timing deficits may be an intrinsic or causative element of the disorder remains to be determined. The present chapter will explore the notion of autism as a social timing disorder, first by considering timing phenomena in the context of typical child development and, subsequently, by reviewing what is known about altered timing in autism.

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2 Social Timing in Typical Development

2.1 *Neonatal Preparedness for Engagement in Social Timing*

Feldman (2006, 2007b) outlines a biological propensity towards social rhythms. Allman, DeLeon, and Wearden (2011) observe how rhythmic changes in the seconds to minutes range often characterise biological systems and infant patterns of movement (for example, breathing, stereotypies, and babbling; Wolff, 1991). Neonatal activities, such as crying and sucking, typically comprise burst-pause rhythmic patterns (Wolff, 1991) that function and provide a structure for initial communication (Burke, 1977; Crook, 1979; Wolff, 1967). These are reflected in the burst-pause patterns of playful face-to-face interaction with young infants (Tronick, Als, and Brazelton, 1977) outlined in Section 2.4.2 later in this chapter.

2.2 *Typically Developing Infants' Perception of Duration, Rate, Rhythm*

At birth and even in the fetus, infants perceive time and have been shown to estimate durations of events (Decasper and Carstens, 1980; 1981; DeCasper and Fifer, 1980). Lewkowicz's (2000) review of infant perception of temporal information concluded that, within their first month, infants can discriminate unimodal auditory duration changes of 20ms as well as distinguish rhythm and rate. By 4–5 months infants can more finely discriminate duration, rate, and rhythm.

There is electroencephalography (EEG) evidence of the scalar property in 6 months olds tested during a task of interval timing and there are measurable developments in their ability to time interval durations over the subsequent few months (Allman, Pelphrey, and Meck, 2012, for a review; Brannon et al., 2004, 2008). Characteristically, interval timing shows scalar variability, i.e., there is a linear increase in the standard deviation of timing errors as the size of the test interval increases. Scalar timing is also identified later in this chapter as a feature of preverbal interaction in typical development. Developments in judgment of interval timing, from 6 to 10 months, may relate to the developments in temporal synchrony, over the second half of the first year, these are also outlined below in Section 2.4.2.

2.3 *Typically Developing Infants' Perception of Intra vs. Inter-sensory Synchronies (Re: Social and Non-social Stimuli)*

There are reports for perception of synchrony by 15–20 week olds and even newborns (Lewkowicz, 2000; Spelke and Cortelyou, 1981). Dodd (1979) presented 10- to 16-week-old infants with synchronous and asynchronous experiences of communication. Nursery rhymes were delivered through an auditory stimulus and lip movement display lasting approximately 4 minutes. The asynchronous display was anomalous by 400ms. Polygraphic measures showed that the infants showed preference for the synchronous presentation, suggesting affinity for the congruence of both auditory and visual information in speech.

Lewkowicz (2000) reports that infants gradually develop from a uni-sensory model (focusing on any one aspect of the stimulus either visual or auditory), progressing to a multi-sensory model between 4 and 8 months of age. At 4 months old they attend only to the featural (e.g., changes in visual characteristics like old/new face, gender, etc.) information whilst at 6 months they focus on asynchrony (e.g., mismatched auditory and visual information). But by 8 months old they achieve the ability to focus on each of these features independently and can process stimuli in a multi-model system.

Lewkowicz's (2000) review confirms that infant preference for synchrony extends to non-facial stimuli. Following familiarisation to synchronised presentations of auditory and visual stimuli, a sequence of asynchronous presentations was presented whereby the sound preceded or followed the visual stimulus. In adults, the threshold for asynchrony discrimination of sound preceding the visual stimulus was 65ms whereas it was significantly larger in infants (i.e., 350ms). When the sound followed the visual stimulus, adults detected asynchrony at a threshold of 112ms and infants at 450ms. A perceptual window of auditory-visual temporal synchrony and asynchrony was therefore postulated which becomes refined as the infant develops towards adulthood (Lewkowicz, 1996). Parameters of an inter-sensory temporal synchrony window for autism are considered later in this chapter (e.g., Section 3.3.2.3).

2.4 *Typically Developing Infants' Active Participation in Social Timing*

2.4.1 Intra-personal Timing in Typical Infants: Expressive Preverbal Babbling

L.A. Petitto studied hearing infants, in the second half of their first year, who were raised in the unusual circumstances of being exposed to signed, but not spoken, communication (Petitto et al., 2001, 2004). They produced "manual babbling" with rhythmic movements of the hands at a frequency (approximately 1 Hz) that contrasted with both their non-linguistic rhythmic hand activity and those of speech-reared infants (approximately 2.5 and 3 Hz, respectively). Petitto et al. (2004) concluded that these cross-modality findings indicate an innate sensitivity to specific rhythmic patterns at the core of human language and capacity to employ them (Petitto et al., 2000, 2001, 2004).

These findings complement those from Positron Emission Tomography (PET)/Magnetic Resonance Imaging (MRI) brain scanning research, showing that the brains of both deaf signers and hearing controls have tissues (e.g., the planum temporale) that are specifically sensitive to *rhythmic* patterns underpinning the structure of natural language (Petitto et al., 2000). Petitto et al. (2004) conclude that this rhythmic element is a fundamental abstract property of language that transcends the mode of communication (speech or sign-language). They further argue that this underpins the evolution, acquisition, and experience of language in humans (Petitto et al., 2004). Other aspects of intrapersonal timing in typical development, for example, prosody and rhythm/syllabicity in speech articulation, are covered through examination of control data that is outlined within Section 3.3.1 later in this chapter (Oller et al., 2010; Peppe et al., 2007, 2011).

2.4.2 Inter-personal Timing in Typical Development: Developments in Temporal Synchrony during Social Interaction

Feldman (2007b) informs the literature reviewed below and outlines three temporal parameters of interactional synchrony, functionally defined by their respective measurements. These are outlined as: (i) concurrent synchrony, where coherence is determined by the degree of matching between behaviour/states; (ii) sequential synchrony, where one partner's behavior/state leads another's, as determined by lead-lag analysis; and (iii) organised synchrony, whereby an ongoing patterned format is measured through time series analysis to determine time-lag associations between each partner's behavior streams once individual's periodicities have been removed.

Both (i) and (ii) form components of (iii) and a developmental perspective is employed below to outline developments in communicative synchrony over the first year of typical development. In short: the coherence of matching in mother–infant dyads (i, above) remains constant over this period (Feldman, 2005). Sequential synchrony (ii, above) shows an increasing decrease in the time-lag to synchrony from 3 to 9 months (Feldman, Greenbaum, and Yirmiya, 1999); and, the infant takes an increasingly responsive role in organized synchrony (iii, above) so that mutual synchrony is achieved by about 9 months (Stern, 1985).

Early observations indicated that newborns show 'entrainment' of limb movements to the syllabic rhythms of maternal speech in any language (Condon and Sander, 1974). Such observations have been supported through a musical type of temporal analysis of infant–parent interaction showing that newborn infants, through movement or vocalization, can synchronize exactly with particular salient moments in adult communication (Malloch, 1999). Even very low birthweight premature infants show such linked sequences between their movements and adult behavior (Eckerman et al., 1995).

Pioneering research by Stern (1977; Stern et al., 1977), using a solely durational approach, demonstrated that cross-modal timing structure operates in maternal communicative actions. Recognisable similarities are repeated fairly regularly across rhythmical action/vocal patterns, within burst-pause formats that fluctuate slightly around an average established tempo (Jaffe et al., 2001).

Sequential patterns between parent and infant communication frequently result in rhythmically chained interactive behaviours with stochastic organization (Gottman, 1981). Cycles of infant states are reflected in these stochastic processes (Cohn and Tronick, 1988). The latter are characterized by rhythmicity within a system of probabilities, whereby events can reliably predict subsequent ones, although the whole series itself lacks predetermined regularity (Di Paolo, 2001; Gottman, 1981).

Feldman's (2007b) review clarifies how the tendency of each communicative partner, to cycle independently between states, accounts for greater variance than does the cross-correlational early interaction data. It concludes that internal rhythmicity plays an important role in determining social interactions from infancy to adulthood, supported by data from both adult–adult (Warner, 1992) and adult–infant interactions (Feldman et al., 1997).

During early proto-conversations, turn taking in the infant–parent dyad is established at a slow beat of 1 per 900ms at 6 weeks old. The beat of shared infant–parent vocal play during animated games then accelerates to 1 beat per 700–500ms within the next month or two (Trevarthen and Aitken, 2001). Stern (1977; Stern et al., 1977) originally showed how the timing structure of maternal behaviour transcends modality. Jaffe et al. (2001) highlight how the variation of repeating patterns of rhythmical actions and vocalisations around an average tempo enables infant–parent dyads to co-create expectancies. This is recognised as a critical achievement in initial social relating, social cognition, and enculturation (Bruner, 1975; Haith, Hazan, and Goodman, 1988; Lewis, Goldberg, and Campbell, 1969).

Stern and Gibbon's (1979) solely durational approach, demonstrated a scalar timing process, whereby, within the durations of maternal repetitive kinesic and vocal behavior, the ratio of the mean to the standard deviation remains constant. They predicted that infants must also therefore use scalar timing processes to decode such temporal information. Zlochower and Cohn (1996) subsequently found that scalar timing is shown in the vocal timing of typical mother-4 month old infant dyads.

The structure of parent–infant interaction begins to be temporally well defined by 2–3 months with respect to matching, sequential linking, and time-series aspects. At this time, interactions comprise behaviour within "repetitive rhythmic cycles" of varied modalities such as indicators of arousal, posture, gaze, emotional expression, and hand movements including touch (Feldman, 2007b). From this age infants start to regulate parental emotions and parents reciprocate this (Trevarthen and Aitken, 2001).

Feldman (2007b) describes how the third month is characterised by the establishment of conventional synchrony, whereby separate "interactive behaviours" are expressed cross-modally in a pattern of continuous coordination. Shared gaze is the main modality of coordinated engagement at 3 months of age, characterizing this for a third to half of the time (Fogel, 1977; Harel et al., 2005; Messer and Vietze, 1984; Pawlby, 1977; Tronick, Als, and Brazelton, 1980).

Shared gaze affords a structure for coordinating the behavioural expressions of other modalities. For example, mutual vocalizations begin at this time, often accompanying shared gaze (Beebe and Gerstman, 1980). This 'coactive mode' is typical of 4-month olds' vocal and kinesic preverbal conversations (Jasnow and Feldstein, 1986). At this age, interactive turn taking is characterised by highly specific matching of such rhythm cycles (Beebe, Stern, and Jaffe, 1979) and computerised-acoustic analysis has shown infant vocalisations in time with maternal nursery rhyme chanting (Malloch, 1999; Malloch et al., 1997).

By 5 months, 1 second frame coded time-series analysis shows timed configurations of face-to-face engagement integrating shared gaze, co-vocalising and affectionate touching (Feldman, 2003). Overall, shared gaze decreases by approximately a third from 3 to 9 months, as typically developing infants develop their abilities in sharing their attention to objects (Landry, 1995). However, touch synchrony increases over this period (Granat, 2005, cited by Feldman, 2007b). For 3- to 4-month olds, synchronous interactions usually features infant-*leading* with mothers-*following*, at a time lag to synchrony of between 1.5 and 2 s (Feldman et al., 1996; Feldman, Greenbaum, and Yirmiya, 1999). Feldman (2007b) highlights how such parameters are very sensitive to biological risk in infancy.

Nine months olds show increasing readiness to be swayed by parental behaviour, thereby precipitating bi-directional mutual synchrony, where both partners respond to one another's rhythms (Feldman, 2005; Stern, 1985). However, the overall coherence of mother–infant synchrony remains stable over the first year (Feldman, 2005) as the infant time lag to *mutual* temporal synchrony parameters decreases from 3 to 9 months (Feldman et al., 1996; Feldman, Greenbaum, and Yirmiya, 1999). Nine months olds are also characterised by a decrease of the co-active mode (outlined above) whereupon the use of switching pauses (silences between turns) develops, so marking the boundaries of "conversational" turns, and enabling more conventional vocal, and ultimately verbal turn-taking (Jasnow and Feldstein, 1986).

There is matching of the switching pause durations of conversational partners within both mother–infant and adult dyads (Beebe et al., 1985, 1988;

Jasnow and Feldstein, 1986). The positive correlation that they show indicates that each partner similarly regulates the exchange: both pausing for a similar duration before taking their turn. Matching of preschoolers' switching pauses occurs before matching of the pauses within their turns, whilst child-to-child switching pauses begin to match from 5 to 7 years. Temporal synchrony is achieved in spoken conversations by 6.5 years, whereby the average pause durations within and between conversational turns are statistically similar (Welkowitz, Cariffe, and Feldstein, 1976).

Tronick and Cohn (1989; Tronick, 1989) observed that whilst most mother–infant interaction comprises mismatched states, most of these are repaired in the subsequent step(s). Therefore, preverbal interaction affords typically developing infants with sophisticated experience of an essentially negotiable process of co-regulation whereby mutual correction to attunement becomes a familiar part of ongoing relationships (Feldman, 2007b). This highlights qualities that remain missing from the interactions of people with autism throughout the lifespan, as outlined later in this chapter.

By the end of the first year, established nonverbal synchrony incorporates symbolic functioning, including gesture and spoken language (Bates, O'Connell, and Shore, 1987). Social use of language is acquired through such proto-conversations (Bates, Camaioni, and Volterra, 1975; Ninio and Snow, 1988, 1996). How frequently 4 month olds vocalise is predictive of Bayley developmental scores at 1 year whilst 3 month olds' responsivity of vocalising to their mothers (as opposed to strangers) predicts verbal cognitive scores at 3, 5, and 12 years (Roe, McClure, and Roe, 1982; Ruddy and Bornstein, 1982).

Tallal's (2004) review of communicative timing in language disordered and typically developing children observes that language development is predicted by early individual differences in Rapid Auditory Processing. Temporal/synchrony aspects of preverbal interaction are explored as developmental correlates of other aspects of typical development in the subsequent section of this chapter.

2.5 *Developmental and Physiological Correlates of Temporal/Synchrony Aspects of Preverbal Interaction in Typically Developing Infants*

The developmental correlates of preverbal interaction/temporal synchrony link physiological and behavioural phenomena; all have relevance to autism, especially those pertaining to attachment, symbolic play, Theory of Mind (ToM), and empathy. They vary from physiological factors that predict parameters of temporal synchrony months later to specific developmental abilities predicted years later by such temporal parameters.

For example, the neonatal sleep-wake cycles and cardiac vagal tone of 0- to 1-month-old infants, predict their mother–infant synchrony at 3 months

(Feldman, 2006). The level of temporal organisation of 3 months old infants' social attention predicts mother–infant synchrony at 9 months and 2 years (Feldman et al., 1996). Attunement of maternal and infant heart rates has been found during interactive synchrony (Moshe and Feldman, 2006, cited by Feldman, 2007b).

Coordination of bi-directional vocal timing measures (e.g., rhythmic coupling and bidirectional coordination) in the 1:1 interactions of 4 month olds with their mothers and with strangers predicts cognition at 1 year (Jaffe et al., 2001). More specifically, mid-range levels of vocal synchrony at 4 months predict security of infant attachment at 1 year (Jaffe et al., 2001). Mother–infant synchrony at 9 months also predicts cognition and self-control/regulatory skills at 2 years (after separating out possible effects of maternal style and infant IQ and temperament; Feldman, Greenbaum, and Yirmiya, 1999). This is built on earlier studies showing a linear relationship between face-to-face synchrony in infancy and better cognition levels in childhood (Feldman et al., 1996; Kirsh, Crnic, and Greenberg, 1995; Murray et al., 1996).

Infants' affect regulation (a nonrandom, stochastic-cyclic organization of affective states, coded from 250ms time frame analysis at 3 months) predicted all three areas of symbolic competence assessed at 2 years, including symbolic play and use of internal state terms, the latter are considered to be a precursor of ToM (Feldman and Greenbaum, 1997). Infant social gaze switching during infant–adult interactions have also been found to predict the ToM abilities at nearly 4 years (Charman et al., 2000).

Findings that face-to-face synchrony measures in infancy also predict better social-emotional adaptation (Feldman and Eidelman, 2004; Harrist et al., 1994) may be related to developments in both ToM and empathy. Face-to-face synchrony in the infant's first year has been found to predict empathy at 13 years (Feldman, 2005; Feldman, 2007a) and ToM at 5 years (reported for premature infants by Feldman, 2007b). Both interactive temporal synchrony and temporal processing in autism are considered in the following sections.

3 Social and Non-social Timing Anomalies in Autism

3.1 *Temporal Synchrony in Autistic Infancy and Childhood*

The subsequent sections on autism employ 'Autistic Disorder (AD)' to refer to the more severe manifestations of the condition and 'Autistic Spectrum Disorders (ASDs)' to refer to a range of more heterogenous related conditions pertaining to less severely affected individuals. Affected people of average or above average intelligence, without early language impairment, are referred to as having 'Asperger's Syndrome (AS)', 'High-Functioning Autism (HFA)' refers to those affected individuals who are also intellectually average, or able, but whose developmental history shows early language impairment. Where appropriate, there is a distinction made between high functioning AD and high functioning ASDs.

There are only a limited number of studies of synchrony in autism during infancy; two are twin studies. An early fraternal twin study unexpectedly observed a 4-month-old (later diagnosed) autistic infant who showed a lack of interactive turn taking in contrast to his typically developing (TD) sibling (Kubicek, 1980). This study employed continuous analysis of interactions to the accuracy of 1/24 s. The ASD infant's responses resembled those of TD infants interacting with their mothers over a time-delayed video-link whereupon the infants showed distress and avoidance, such as looking away (Murray and Trevarthen 1985; Nadel et al., 1999).

Hedenbro and Tjus (2007) studied a child, later diagnosed with both AD and 'mental retardation', from 3 to 48 months along with a cohort of TD children. Whilst a *temporal* synchrony approach was not employed, the study focused on dyadic and triadic synchrony between the child and her parent(s). The most obvious differences between the AD child and the TD cohort appeared when she was 9 months old. This is the age at which genuinely mutual temporal synchrony is typically established, as outlined in earlier sections of this chapter.

Temporal synchrony measures particularly focus on the flow of interaction within a dyad. Trevarthen and Daniel (2005) specifically applied these criteria to a pair of monozygotic (MZ) twins at 11 months. The study is unusual in that the video-recorded 1:1 adult:infant interactions were analysed to a resolution of 0.04 s. The twin later diagnosed with AD showed no well-timed co-regulation whilst the TD twin showed synchrony as well as cyclic reciprocation of expressions. Unfortunately, subsequent ASD studies (as reviewed in the paragraphs that follow) with larger infant numbers have not employed the fine resolution of Trevarthen and Daniel's temporal synchrony research.

Rozga et al. (2011) employed 1 and 5 s windows to analyse mother–infant free play and the effects of maternal still face procedure; however, this did not distinguish 6 months old who were later diagnosed with ASD from those who were later undiagnosed. Possibly higher temporal resolution of the infant–caregiver interactions and analysis over a longer duration might show differences in early social interaction of the infants with autism. Rozga et al. acknowledge that such a microanalytic approach to infant timing may have proved more productive. They cite Yirmiya et al. (2006) who, at a 1 s resolution, showed decreased synchrony in the infant–led interactions of unaffected siblings of children with autism.

In contrast to research employing individually based counts of social behaviour, synchrony-based videotape analysis has been able to distinguish (on the basis of social orientation) the first 6 months of infancies later diagnosed as AD (with Learning Disabilities, LD) from controls with TD or LD that remained undiagnosed (Saint-Georges et al., 2011).

A retrospective parental interview study found that interactive turn taking distinguished infants with autism (mostly AD, including some with developmental delay) from matched control infants with only developmental delay (Wimpory et al., 2000). It may be that the responsiveness or repertoire of infants and young children with autism makes temporal synchrony harder for parents to achieve with them. The prosody element of this is considered below in Section 3.3.1.

The chronographic presentation of verbal high-functioning adolescents and young adults with autism has been analysed during conversations by quantifying the structure of their vocalizations and silences with an interviewer in contrast to those with their parents (Feldstein et al., 1982). This revealed longer switching pauses for autistic participant–parent interaction as compared to parent–experimenter, and there were both longer pauses and switching pauses in the autistic participant–experimenter interaction. The findings demonstrated that autistic participants never achieved temporal synchrony in their interaction.

In typical conversations, congruent pattern matching occurs between participants so that the lengths of the pauses covary towards a match in mean pause duration between the conversational partners. TD children, even as young as 6.5 years, exhibit this pause duration synchrony in their conversations (Welkowitz, Cariffe, and Feldstein, 1976) and preverbal use of switching pauses typically develops from at around 9 months, as indicated earlier in this chapter (Jasnow and Feldstein, 1986). In temporal synchrony, the duration of each partner's switching pauses become increasingly statistically similar to the mean over time.

3.2 *Therapeutic Approaches to Synchrony in Autism Integration*

This section briefly considers attempts to facilitate synchrony in parental interactions with their children with autism. A randomised controlled trial of the Preschool Autism Communication Trial (PACT) evaluated the efficacy of specifically enhanced communicative synchrony in parental aspects of communication. This was found to correlate with significant improvement of child communication within the interactions of young autistic AD child–parent pairs (Green et al., 2010). Music Interaction Therapy (MIT) is an intervention aimed specifically at ameliorating *temporal* synchrony problems for young children with ASD during their familiar caregiver's spontaneous attempts to engage them in 1:1 interaction. MIT employs an accompanying musician to offer live timing support in an exaggerated and prolonged experience that aims to recapitulate, and capture the developmental potency of, preverbal interaction (Wimpory, Chadwick, and Nash, 1995).

More detailed temporal analysis of MIT is currently underway for at least sixteen recent cases (Wimpory, Nash, Muth, and Nicholas, in progress). MIT case studies of AD with LD have included findings showing that the child–parent dyad's accompaniment by live musical timing is associated with positive change in relation to previously established developmental trajectories. This has contrasted with, for example, developments recorded in child–parent interactive play during a period whilst the mother received social support, rather than MIT, from the Music Therapist (Wimpory, 1995; Wimpory and Nash, 1999a). Furthermore, communicative gains (in social acknowledgement, eye-contact, child-initiated interactive involvement) associated with seven months of MIT, significantly exceeded developmental trajectories established through 4 months baseline. These gains were maintained at 2 years follow-up (where MIT, for AD with LD, continued for just the initial 5 months; Wimpory, 1995; Wimpory, Chadwick, and Nash, 1995).

Other untrained related developments, such as teasing and symbolic play, were absent during the initial baseline but developed without training during the MIT phase and were maintained at 2 year follow-up where generally continuous child social attentiveness was recorded (Wimpory, 1995; Wimpory, Chadwick, and Nash, 1995). Where parents naturally achieve greater interactional synchrony with their AD child, with LD, this predicts child communication outcomes up to 16 years later (Siller and Sigman, 2002, 2008).

3.3 *Temporal Aspects of Social–Communication Skills in Autism*

3.3.1 Synchrony, Gesture, and Speech

Early research in autism highlighted how such preschool children show a delay in responses of a full second in some instances; this was noted as excessively asynchronous in comparison to the rapid responses of TD children (Condon, 1975; 1979). In more recent behavioural assessments of the perception of synchrony, 4–6 year old children with Autism (and TD and language-matched developmentally delayed controls) gave increased attention to temporally disturbed non-linguistic audio-visual stimuli (asynchronous by 3 s; Bebko et al., 2006). However, in contrast to both control groups, the children with autism were insensitive to disturbed temporal linguistic synchrony.

Deficiencies in gestural-speech synchrony have been found in the expressive communication of young people with HFA, AS, and ASD. Although the frequency of their gestures was comparable with those of typically developing adolescents during a standardised story-telling situation, the timing of their gestures (in relation to their speech) impacted negatively on the quality of their narrative. More severe autistic symptom scores correlated with worse quality ratings for story telling using a story telling element of the Autistic Diagnostic Observation Schedule (ADOS; De Marchena and Eigsti, 2010). Preschool children with AD and ASD are disinterested in the motherese that usually facilitates preverbal interaction (Klin, 1992; Kuhl et al., 2005, respectively). Indeed, children with autism HFA prefer synthesised voices that lack prosodic intonation (Burack et al., 2001). Prosody is the rhythm and intonation of speech that conveys nuances of emotion and meaning. Expressive and perceptive prosody difficulties characterise even HFA in both adults and children (Hesling et al., 2010; Peppe et al., 2007, 2011, respectively). Where TD, HFA, and AS groups are matched on expressive language, sub-group differences in expressive prosody emerge independent of language levels (Peppe et al., 2011).

Expressive and perceptive prosody difficulties are linked in autism (with respect to affect, emphasis, and rhythm; Hesling et al., 2010). Hesling et al. (2010) employed functional Magnetic Resonance Imaging (fMRI) to demonstrate that the neural network involved in prosody perception shows abnormal activation in the left Supra Marginal Gyrus (SMG) in HFA, correlating positively with intonation and emphasis. Such prosody tasks depend on both spectral and temporal information processing.

An acoustic analysis of children's voice spectra showed that rhythm/syllabicity was strongly correlated with, and predictive of, age in TD children. This association did not hold for the children with autism (Oller et al., 2010). Their abnormal temporal processing of the auditory stimuli in speech is considered below, along with other aspects of temporal processing findings that have been derived from a communicative context.

3.3.2 Temporal Processing in Autism

3.3.2.1 *Processing Speed Findings Derived from Social/Communication Stimuli*

An early study of left hemisphere recording sites showed that the Event-Related Potential (ERP) P300 response is reduced for phonetic stimuli in older children with autism with and without LD (Dawson et al., 1988). Children and adults with AD and HFA are often more able than TD controls to process simple auditory stimuli, like the (perfect) pitch of pure tones (Bonnel et al., 2003; Heaton et al., 2008; Lepistö et al., 2008) but less able to process auditory material that is more spectrally and temporally complex (O'Connor, 2012). It may be that the ERP findings of impaired semantic processing in AS and HFA are better interpreted through the enhanced visual processing effects outlined in the integrated timing section below (Russo et al., 2012). However, resultant functional timing difficulties could still adversely affect crucial timing aspects of early (and subsequent social) interaction outlined earlier in this chapter.

Visual ERP research in ASD shows delays in both perception and response systems with regard to facial stimuli. These are in addition to abnormalities in the temporal processing of auditory stimuli in speech. For example, there is delayed latency of the face-processing N170 component during passive observation of faces in HFA, AS (McPartland et al., 2004), and AD with LD (Webb et al., 2006). There are also ASD delays in the N300 component, which responds differentially to fearful faces. Dawson et al. (2004) found that these predict social orienting, joint attention skills, and time spent looking at a person expressing distress, in a sample of ASD and AD young children, mostly with LD.

Oberman, Winkielman, and Ramachandran (2009) found other evidence of temporal processing timing anomalies in high functioning AD and ASD in response to social stimuli, with no group differences either for intentional behavioural mimicry or for amplitude or selectivity of emotion-relevant electromyography (EMG) activity. However, there was delayed spontaneous mimicry in ASD across various stimulus presentation durations and expressions; this delay was longer (approximately 160ms) than the perceptual delays typically observed in ERP studies (approximately 20ms).

3.3.2.2 *Processing Speed: Findings Generally Derived from Non-social/Communication Stimuli*

This section represents more recent developments from earlier research noting apparent temporal anomalies in rapid attention-switching in ASD older children and adults, for example, between spatial locations (Courchesne et al., 1994a,b, for AD/HFA; Haist et al., 2005, for AD/HFA and AS; Townsend et al., 2001, for AD/HFA; Townsend et al., 1999, for HFA). One physiological indication of a temporally anomalous alternative mode of processing is that peripheral visual stimuli produce a delayed frontal late positive ERP component in children with autism. This indicates a specific delay in spatial attention orientating, even when rapid attention-shifting demands are removed, and HFA subjects produce normal behavioural output (Townsend et al., 2001).

Magnetoencephalography (MEG) also shows altered temporal measures of processing in autism, indicating a disruption in encoding simple sensory information: an auditory evoked and characteristic neuromagnetic field response from the Superior Temporal Gyrus (STG) was delayed by 11ms in ASD (Roberts et al., 2010). Roberts et al. quantified a positive predictive value (PPV) of 86% for this electrophysiological measure for autism (with or without language impairment).

Allman (2011) highlights how social cognition is critically dependent on adaptive sensitivity to the duration of events and their intervening periods. Contradictory ASD findings concerning temporal processing of the shortest duration range may be due to methodological considerations, for example, tasks may or may not allow dependence on memory or counting strategies. Nevertheless they demonstrate at least a functional timing problem relevant to the speed of early and later social interaction. For example, difficulties have been found at the 0.4–0.8, 1–5.5, 1.7–4.1, and 0.5–2 s level (respectively, by Gowen and Miall, 2005, for older children and adults with AS; Szelag et al., 2004, for AD/HFA children; Martin, Poirier, and Bowler, 2010, for high functioning adults with ASD; and by Maister and Plaisted-Grant, 2011, for children with high functioning Autistic Spectrum Conditions). However, neither Mostofsky et al. (2000) found these at the millisecond level for HFA children nor did Martin, Poirier, and Bowler (2010) find them below 1.7 s for high functioning adults with ASD.

Allman, DeLeon, and Wearden (2011) studied perception of duration in high functioning children with ASD (mostly AD) using temporal bisection procedures (with 1–4 and 2–8 s standards). They found proportionally more responses that were too long, and an extinction effect in their precision to estimate durations longer than 5 s. Subsequently, Falter et al. (2012) tested visual, auditory, and cross-modal interval timing for 0.6 and 1 s standards in adolescents and adults with high-functioning ASD and TD controls. They found that the ASD group showed a clearer presentation of the scalar property (a characteristic of interval timing) but less ability to discriminate correctly whether the test stimuli were longer or shorter than the standards. The ASD group also showed a more conservative response bias.

Although Maister and Plaisted-Grant (2011, c.f. above) found no ASD deficit regarding reproductions of 4–30 s durations, they did find impairment of longer duration reproductions (45 s). Their paradigm removed opportunities for reliance on chronometric counting. Memory testing indicated possible episodic memory effects for the 45 s anomaly in the ASD group.

A publication by Gil et al. (2012) concluded that the substrates for time perception are intact in ASD. However, 75% of the 12 subjects in this study had AS (the remainder of this high-functioning sample had HFA or Pervasive Developmental Disorder-not otherwise specified: PDD-NOS). Gil et al.'s conclusions might therefore be more applicable to AS. The overall picture is not clear-cut, but even taking into account the only two other studies that did not find evidence of short interval timing deficit in older children with HFA (Mostofsky et al., 2000) or with AS or high functioning ASD (Wallace and Happe, 2008), it appears that there is, overall, empirical evidence for timing anomaly in ASD.

3.3.2.3 *Temporal Integration* (*Perceptual Simultaneity, Multisensory/ Temporal Binding, Local to Global/Integration over Time/Context*)

Difficulties/delays in integrating visual and auditory stimuli are noted in ASD and AS (Iarocci and McDonald, 2006; Kwakye et al., 2011). There are both increased errors in multi- and uni-sensory (e.g., auditory) temporal order judgement (Kwakye et al., 2011) in ASD whilst enhanced performance on perceptual simultaneity tasks indicates lower thresholds for vision in HFA and AS (Falter, Elliott, and Bailey, 2012). ERP evidence indicates that the parameters of semantic multisensory integration in ASD depend on both timing and modality order. In response to simultaneous presentations, congruent and incongruent waveforms diverge almost twice as fast in subjects with ASD (at around 0.15 s) than in TD individuals (Russo et al., 2012). Selective sensory temporal enhancement, of visual over auditory stimuli, correlates with sub-clinical ASD traits (Donohue, Darling, and Mitroff, 2012).

Russo et al. (2012) argue that enhanced processing speed in the visual domain may account for the wider temporal window reported in autism in which two cotemporaneous events (e.g., visual and auditory) are perceived to occur simultaneously (Foss-Feig et al., 2010 for high-functioning ASD and AD; Kwakye et al., 2011 for high functioning ASD and AS). Sound is processed faster that vision in the neurotypical brain and this differential may need to be maintained for neurotypical functioning (Der and Deary, 2006). The interdependency of the wider temporal binding window in ASD (Foss-Feig et al., 2010; Powers, Hillock, and Wallace, 2009) and the other difficulties, with multi-/ uni-sensory temporal order and perceptual simultaneity, await clarification.

Disordered visual processing in ASD adults has been linked to oscillatory brain activity involved in neural binding (Grice et al., 2001). Gamma oscillation, a correlate of neural binding, is also anomalous in children with ASD (Brown et al., 2005). Furthermore, difficulties have been shown in ASD adults integrating local visual information into a global whole specifically over time (Nakano et al., 2010). Episodic memory, characterised by contextual specificity, pertains to the integration of information over time and depends on intact timing mechanisms to appropriately encode temporal and non-temporal contextual information. Episodic memory anomalies are found in individuals with autism (Millward et al., 2000) including HFA and AS (Boucher and Lewis, 1989; Bowler, Gardiner, and Grice, 2000; Salmond et al., 2005). Finally, problems with diachronic thinking, or thinking about time, are also characteristic of ASD including AS (Boucher et al., 2007).

3.4 *Motoric Timing Anomalies in Autism*

Whilst this chapter specifically focuses on temporal anomalies related to aspects of social communication in ASD, temporally measured motoric anomalies may also impact on these and/or inform understanding of relevant processes involved. For example, Gowen and Miall's (2005) assessments of adults with AS revealed motor coordination difficulties that are behavioural aspects of cerebellar function. The motor coordination temporal anomalies covered in this section range from, for example, posture to eye-blink. Their neurological implications and specific neurological findings for ASD are the focus of the subsequent section.

Temporally measured postural anomalies have been reported for HFA by Schmitz et al. (2003) and Minshew et al. (2004). With respect to classical eye blink conditioning, Sears, Finn, and Steinmetz (1994) found subjects with autism (including HFA) to be quicker at learning and un-learning the classically conditioned eye blink response. Furthermore, and in contrast to TD children, age did not modulate the process in autism, as the younger autistic children were as able as the older autistic children in acquisition and extinction.

Inui and Asama (2003) tested the bimanual finger tapping ability of children with LD and children with autism and LD. The autism group differed from both the TD controls and from the LD group. Those with autism produced faster rhythms in each of the tests at each of the required tempos (inter-tap intervals 200, 400, and 800ms), while the LD group showed only increased tapping speed in the 800ms test.

Altered motor behaviour in autism is not limited to the fine movements investigated in the above experiments. Vilensky, Damasio, and Maurer (1981) found anomalies in the gait of autistic individuals comparable with Parkinson's disease (PD). Rinehart et al. (2006) used gait analysis to conclude that both HFA and AS individuals are uncoordinated. Mutation of the circadian ubiquitin ligase *HERC2* is also causative of a phenotype of gait disturbance, nonsyndromic intellectual disability, and autism (Puffenberger et al., 2012).

3.5 *Timing-Related Brain Anatomy and Neurological Findings in Autism*

The temporally measured motor coordination anomalies outlined above implicate the cerebellum, cerebellar-hippocampal circuit, and basal-ganglia/frontostriatal region in autism (Rinehart et al., 2006; Sears et al., 1994; Vilensky et al., 1981) and cerebellar function and the basal-ganglia/frontostriatal region in AS (Gowen and Miall, 2005; Rinehart et al., 2006). Drawing overall conclusions from brain structure studies in autism is difficult due to inconsistency in: the degree of autism, participant's age, intelligence, and comorbidities across the different studies. Nevertheless, the cerebellum has long-remained a focus of interest with findings of cerebellar anomalies in autism (Bauman and Kemper, 1986) including HFA and AS (Scott et al., 2009). Cerebellar Purkinje neurons function in learning appropriate timing (Koekkoek et al., 2003; Kotani, Kawahara, and Kirino, 2003). It is therefore of interest that a reduction in Purkinje cell number is reported for autism (Kemper and Bauman, 2002; Ritvo et al., 1986). This may underlie other observations of cerebella dysfunction in the disorder (Courchesne, Townsend, and Saitoh, 1994).

Involvement of the cerebellum is reinforced by consistent genetic findings of association of the *EN2* gene with ASD (Benayed et al., 2005; Gharani et al., 2004). *EN2* regulates cerebellum development (Sillitoe et al., 2008), as does the clock gene, *RORA* (Boukhtouche et al., 2006) that shows altered methylation and expression patterns in individuals with autism (Nguyen et al., 2010).

Nuclear magnetic resonance imaging in autism (including high-functioning ASD) highlights regions of the temporal lobe (Ecker et al., 2010; Salmond et al., 2005). fMRI indicates altered intra-brain communication between neural networks (Williams and Minshew, 2007) that is supported by previous findings of a reduction in long-range axons in ASD shown through Diffusion Tensor Imaging (DTI; Barnea-Goraly et al., 2004). Atypical development of cerebellar systems and connection to the cortex are reported (Courchesne, 1997). These systems govern sensory and motor signal integration (Ivry et al., 2002). Altered connectivity that could impact temporal integration is also seen in anatomical differences in the corpus callosum, the brain's interhemispheric portal, in child and adult subjects with AD, some of whom also have LD (Piven et al., 1997).

3.6 *Physiological/Circadian-Related Aspects of Timing in Autism (Sleep Wake Cycle, Melatonin, Clock Genes, and Cardiac Vagal Tone)*

Sleep disturbance is associated with autism (AD, HFA, and AS, as well as low functioning autism: Elia et al., 2000; Limoges et al., 2005; Richdale and Prior, 1995). Measures of melatonin that regulate sleep timing, and its precursor, serotonin, are also disturbed in both adults and children (Cook and Leventhal, 1996; Nir et al., 1995; Richdale and Prior, 1992). A system of rhythmically expressed clock genes drives the circadian rhythm in melatonin production and time of day effects on timing performance are noted in humans (Aschoff, 1998).

Clock gene mutations modulate high frequency oscillators involved in fruit fly communication (Kyriacou and Hall, 1980) and pulsed hormone secretion in hamster (Loudon et al., 1994). Variation in clock genes in human populations are relevant to affect and cognitive processes (Lavebratt et al., 2010; Terracciano et al., 2010; Utge et al., 2010), and may be relevant to autism (Wimpory, Nicholas, and Nash, 2002); these points are outlined in more detail in Chapter 13 of this book. The association of clock gene variants, altered clock gene expression in twin studies and altered clock gene methylation patterns (case control) in autism support this hypothesis (Hu et al., 2009 for high functioning ASD; Melke et al., 2008 for ASD with and without LD; Nguyen et al., 2010 for high functioning ASD; Nicholas et al., 2007 for high functioning AD).

Sleep-wake cyclicity and cardiac vagal tone (circadian regulated) anomalies are associated with autism (Ming et al., 2005) and are important at a systemic level (Field and Diego, 2008). Measures of both sleep-wake cyclicity and cardiac vagal tone predict mother–infant synchrony in typical development (Feldman et al., 1996; Moore and Calkins, 2004), as outlined above.

4 A Timing-Based Developmental Model of Autism

4.1 *Summary: The Importance of Timing in Autism*

To summarise the earlier sections of this chapter, empirically measured temporal anomalies in autism (including HFA/AS) range from sleep architecture, circadian, and circadian-related hormonal anomalies, to brain oscillations involved in neural binding; temporal processing/interval timing; attention-switching motor coordination and communicative timing. Most importantly, for the model presented below, the temporal anomalies in autism also extend to the reciprocity/temporal synchrony skills required for adult and infant communication that are present from the early months in TD.

Appropriate temporal resolution plays a concurrent role in areas of social–communication relevant to ASD symptomatology, for example in interpersonal perception, communication of mood, empathy, understanding of intentions, and ToM abilities (Baldwin, 1993; Blakemore et al., 2003; Crown, 1982; Feldstein, 1982; Natale, 1976; Tomasello, 1999; Welkowitz and Feldstein, 1970). However, this chapter seeks to build beyond an understanding of the concurrent effects of timing in considering potential developmental effects.

4.2 *Timing Theories of Autism*

Various autism theories have proposed timing difficulties as being central to autism with hypotheses encompassing communicative, neurological and/or circadian aspects of timing (Allman, 2011; Boucher, 2000, 2001; Brock et al., 2002; Courchesne et al., 1994b; Grossberg and Seidman, 2006; Newson, 1984; Richdale and Prior, 1995; Segawa, 1985; Szelag et al., 2004; Welsh, Ahn, and Placantonakis, 2005; Wimpory, Nicholas, and Nash, 2002). For example, Boucher (2001) suggested a core deficit in timing due to systemic damage to an integrated system of neural and physiological oscillators.

Wimpory, Nicholas, and Nash (2002) proposed a causative, concurrent and developmental role for timing deficit in AD, suggesting that this deficit involved pathological variations in the structure/function of clock/clock-related genes.

However, it may be that *any* biological disruption of preverbal temporal synchrony, for example, through deaf-blindness (Fraigberg, 1977) may give rise to the more heterogenous presentations of ASD now more widely diagnosed.

This chapter conceives the timing deficit in autism *per se* as manifest through both temporally measured anomalies and apparently disparate symptomatology. It builds on the argument that there may be some temporal and/or clock gene dependency within what may otherwise appear to be disparate autism symptoms (Nicholas et al., 2007). Whilst the impact of temporal resolution on communication has been outlined above, cross-species research shows that functional variations in clock genes concomitantly influence circadian rhythms, emotional contextual memory (Garcia et al., 2000), and short period timing phenomena (Beaver and Giebultowicz, 2004; Kyriacou and Hall, 1980; Loudon et al., 1994) with possible relevance to: autistic communication; diachronic thinking (Boucher et al., 2007); and, perceptual learning (Plaisted, O'Riordan, and Baron-Cohen, 1998).

Perceptual learning generally depends upon sleep-mediated consolidation (Fenn, Nusbaum, and Margoliash, 2003; Karni et al., 1994; Maquet, 2001; Walker and Stickgold, 2004). Thus the perceptual learning deficit in autism may be exacerbated by circadian and sleep disturbance in autism detailed earlier. Clock gene variants can contribute to altered sleep architecture and circadian anomalies as well as other pleiotropic effects (these are concomitant effects of a given gene on more than one apparently unrelated trait). For example, knockout of the clock gene *Npas2* (in mice) reveals its impact upon sleep architecture, circadian rhythms, and emotional contextual memory (Garcia et al., 2000). Sequence variation within the human *NPAS2* clock gene is associated with AD (Nicholas et al., 2007).

Hierarchical accounts of the timing anomalies in autism may, of course, include those that are not dependent on clock genes. For example, as Russo et al. (2012) suggest, enhanced visual processing speed may account for the wider temporal binding window reported in autism (Foss-Feig et al., 2010; Kwakye et al., 2011). Allman (2011; Allman, DeLeon, and Wearden, 2011) builds on both Wimpory and Boucher's theories, to provide a temporal account of autism symptomatology regarding: executive functioning, memory, interactional synchrony, bonding, communication, weak central coherence, perception, restricted and repetitive behaviours, learning and memory problems, etc. (Boucher, 2001; Boucher et al., 2007; Wimpory, Nicholas, and Nash, 2002).

Allman's account assumes that duration sensitivity relates to the subjective sense of time and considers that autistic impairments in ToM, empathy, and imagination, might relate to deficits in the capacity for "mental time travel" (Allman, 2011; Suddendorf and Corballis, 1997). In accounting for these impairments, this chapter now draws on an understanding of the processes involved in typical development and the implications of timing anomalies for such processes in autism.

4.3 *How Typical Development Can Inform Our Understanding of Autism*

4.3.1 Developmental Correlates Relevant to Autism

Whilst there are some skills, relevant to deficits in autism, that may obviously be honed through early preverbal interaction (prosody, turn taking, facial expression, gesture, etc.), the apparent developmental role of early temporal synchrony in typical development may also enhance our understanding of important symbolic functioning deficits in autism. There are autistic deficits in each of the following areas, and each of these are shown to correlate developmentally with typical infant temporal synchrony: symbolic functioning/social pretence, social-emotional adaptation (Feldman and Eidelman, 2004; Harrist et al., 1994), empathy, ToM, and attachment (Jaffe et al., 2001).

4.3.2 Links from Preverbal Timing to Symbolic Functioning in Typical Development

Bergson (1911) originally argued that human experience and consciousness is essentially relational and inextricably linked with our evolved sense of time. The development of interpersonal synchrony, initially dependent on the infant's experience of his/her own rhythmic functions, and then on their relation to those of another, appears to support the development of procedural interactive pre-symbolic knowledge (Jaffe et al., 2001; Stern, 1974, 1985, 1995). More active turn taking, evolving the concept of self and other, may provide the basis for developing declarative knowledge (Feldman, 2007a and b). The appearance of symbolic functioning (at approximately 1 year) may further depend on the creation and acquisition of shared meaning that emerges from timing dependent parent–child interaction (Feldman, 2007b; Newson and Newson, 1975; Wimpory et al., 2000).

Symbols emerge within an interactive context during positive moments between caregiver and child whereby the synchronicity of experience (affective, communicative) is often crucial. Early joint action formats can typically be characterized as "always the same yet always different" (such as 'peek-a-boo' in different contexts, moods, speeds, etc.). Symbols may develop on the basis of playful repetitive encounters within such experiences. During synchronous preverbal interaction a supportive adult's communication may assist an infant in abstracting the shared characteristics of represented phenomenon into a single concept while overlooking minor differences, so enabling its symbolic encoding (Rogoff, 1990; Vygotsky, 1978). TD infants' earliest mental representations likely characterise their significant others, with whom they interact in a temporally specific manner.

Attachments are based around such experiences during a period when capacities for mental acts of substitution and referencing are only just becoming available to TD infants. The referential looking (from a person to an object and back to that person) is just one of the activities that characterises progression from primary to secondary inter-subjectivity (whereby external objects are incorporated into the interaction). Parental referencing of objects, and taking of disparate attitudinal perspectives towards them, is identified by Hobson (1993, 1994) as essential for the typical development of symbolic functioning in infants.

Hobson (1993, 1994) outlines how the disparate attitudes conveyed through parental roles, during the incorporation of joint attention to objects in preverbal interaction, could be pivotal in the development of pretence in TD. Wimpory (1995; Wimpory et al., 2000) has extended this to consider teasing in preverbal social interaction before the incorporation of physical objects into such engagement. Playful teasing by parent and infant is common in the preverbal social interaction of TD infants (Reddy, 1991, 2001, 2008). It is often facilitated through non-verbal play around issues of timing (for example, during the exaggerated speech and rotating hand movements of the action rhyme "s-l-o-w-l-y, s—l—o—w—l-y, *quickly!*"). As in this example, teasing involves playfully sabotaging another's expectations; these are often time dependent. Although this behaviour inevitably involves some mental representation of such parental expectations on the infant's part, it precedes other more formal manifestations of symbolic functioning (Hoicka and Gattis, 2008; Reddy, 1991, 2001, 2008; Trevarthen and Logotheti, 1987).

4.3.3 The Implications for Autism

Wimpory and colleagues have applied the above arguments to autism. In recognising timing as central to the development of social communication and symbolic functioning, they emphasize and report an early inability to partake in the proto-conversations that characterise TD in social communication and symbolic functioning (Nicholas et al., 2007; Wimpory et al., 2000; Wimpory, Hobson, and Nash, 2007; Wimpory, Nicholas, and Nash, 2002). Furthermore, parents of children with autism do not recall them engaging in teasing during infancy (Wimpory, 1995; Wimpory et al., 2000), and the teasing shown by older children with HFA and AS is much more limited (less playful and provocative) than that of matched controls (Heerey et al., 2005). Referential looking predicts ToM, and both these phenomena remain elusive in autism, along with broader aspects of symbolic functioning. Although autistic savants, with higher mathematical capacity, may be using symbols, their abilities do not extend to the full capacity to create symbols, particularly in an interactive context, as characterizes young TD children.

MIT offers opportunities to establish synchronous proto-conversational experience in autism (Wimpory et al., 1995, Wimpory and Nash, 1999b). MIT is recommended early and there is precedent for this conceptualization in the narrow time window during which chicks are able to learn their species-specific song from their parents. If this opportunity is missed, the young birds are not subsequently able to acquire the capacity for meaningful song (Bolhuis, Okanoya, and Scharff, 2010). Furthermore, song learning in birds is regulated by the circadian clock (Cassone and Westneat, 2012). In the fruit fly, *Drosophila*, the courtship song is an innate and genetically programmed behaviour regulated by the circadian clock gene, *period* (Kyriacou and Hall, 1980). Thus, there is cross-species evidence for co-regulation of the circadian clock and social, communicative capacity.

4.3.4 Conclusion

Earlier sections within this discussion draw on typical development to outline how timing anomalies in autism could account for: (i) temporally disabled relations, (ii) an impoverished sense of self and other, (iii) an impaired quality of attachments, and (iv) impaired symbolic functioning in terms of the creation of symbols and development of shared meaning. The focus on timing, as outlined above, has led to investigations identifying variations in clock genes associated with AD (*NPAS2* and *PER1*, Nicholas et al., 2007) as well as to therapeutic facilitation of temporal synchrony through MIT. MIT provides a unique opportunity to test the perspectives presented here; it is now the subject of a larger scale service-based project (Methley and Wimpory, 2011; Wimpory, Nash, Muth and Nicholas, in progress).

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