Heart rate variability during social interactions in children with and without psychopathology: a meta-analysis

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Abstract length: 218

Text length: 5,789

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Declaration of Interests: Ian B. Hickie is a member of the Medical Advisory Panel for BUPA Health Insurance (Australia) and also a Board Member of Psychosis Australia Trust. From 2012, he is a Commissioner in Australia˝s new National Mental Health Commission. He was until January 2012 a director of headspace: the national youth mental health foundation. Professor Hickie was previously the chief executive officer (till 2003) and clinical adviser (till 2006) of beyondblue, an Australian National Depression Initiative. He is supported principally for clinical research in depression and health services and population health initiatives related to anxiety and depression by an NHMRC Australian Medical Research Fellowship (2007–2012). He has led projects for health professionals and the community supported by governmental, community agency and pharmaceutical industry partners (Wyeth, Eli Lily, Servier, Pfizer, AstraZeneca) for the identification and management of depression and anxiety. He has received honoraria for presentations of his own work at educational seminars supported by a number of non-government organisations and the pharmaceutical industry (including Pfizer, Servier and Astra Zeneca). He has served on advisory boards convened by the pharmaceutical industry in relation to specific antidepressants, including nefazodone, duloxetine and desvenlafaxine. He leads a new investigator-initiated study of the effects of agomelatine on circadian parameters (supported in part by Servier but also by other NHMRC funding) and has participated in a multicentre clinical trial of the effects of agomelatine on sleep architecture in depression and a Servier-supported study of major depression and sleep disturbance in primary care settings. In addition to national and international government-based grant bodies, investigator-initiated mental health research at the BMRI, he has been supported by various pharmaceutical manufacturers (including Servier and Pfizer) and not-for-profit entities (including the Heart Foundation, beyondblue and the BUPA Foundation).

Abstract

Background: The inability to regulate autonomic activity during social interactions is believed to contribute to social and emotional dysregulation in children. Research has employed heart rate variability (HRV) during both socially engaging and socially disengaging dyadic tasks between children and adults in order to assess this.

Methods: We conducted a meta-analysis including evidence from eighteen studies comprising 1544 children who were categorised as either healthy or at risk / diagnosed with psychopathology. Within these groups we assessed the impact of social engagement and disengagement tasks on HRV.

Results: Results showed that social engagement tasks left HRV unaltered to a baseline. Social disengagement, however, was associated with decreases in HRV. In a task that included disengagement and then engagement, HRV was reduced during disengagement but was then restored during the reunion phase (engagement). Children at risk or with a diagnosis for psychopathology, however, failed to show any change in HRV during dyadic social interaction tasks. This was despite a social stressor, the Trier Social Stress Task, causing significantly reduced HRV in both groups.

Conclusions: This meta-analysis provides support to suggest HRV may provide a worthwhile context specific marker for the effective regulation of dyadic social interactions in children.

Abbreviations: Heart rate variability, HRV; Respiratory sinus arrhythmia, RSA; Trier Social Stress Task, TSST

Keywords: social behaviour, psychopathology, psychophysiology, Meta-analysis

The development of successful social interaction skills during childhood assists the formation and regulation of relationships with peers, family members and romantic partners throughout life (Feldman, 2007). Competence in social interactions predicts a range of positive outcomes across development including positive social behaviour and assertiveness in preschool settings (Ainsworth & Bell, 1969; Denham, Renwick, & Holt, 1991) and a positive transition to school (Harrist, Pettit, Dodge, Bates, & Bates, 2013).

The study of social interaction involves the observation of physical, verbal or emotional exchanges between two or more individuals (Argyle, 1969). Experimental tasks used with children have included the still face procedure (Adamson & Frick, 2003), the strange situation (Ainsworth & Bell, 1969), teaching tasks (Petrie, Kratochwill, Bergan, & Nicholson, 1981), and free play tasks (Rubin, Maioni, & Hornung, 1976). These tasks can be broadly separated into tasks that encourage social engagement and those that evaluate emotion regulation in response to social disengagement. For example, prolonged free play with a caregiver offers opportunities for social engagement. In the still face procedure, caregivers turn away and are non-responsive to their child for a prolonged period of time and in the strange situation, parents leave the room during a social encounter. These tasks, therefore, assess emotion regulation capacity following social disengagement.

The autonomic nervous system plays an important role in the regulation of emotions during social interaction. The parasympathetic nervous system, attributed to the activity of the myelinated vagus, is associated with a social engagement system that regulates the facial muscles, middle ear muscles and laryngeal-pharyngeal system during positive social interactions (Porges, 2003).

In contrast, the sympathetic nervous system is activated in response to stressful social events and facilitates physiological arousal that aids in adapting to challenging social environments. While these systems support contrasting environmental states, healthy emotional regulation relies on cardiac autonomic nervous system regulation; a rapid modulation of physiology, reflected in efficient control of parasympathetic and sympathetic output (Thayer, Hansen, Saus-Rose, & Johnsen, 2009). Effective social engagement is proposed to reflect both increased activity of the myelinated vagus, leading to a flexible and responsive facial, vocal, and auditory system in the social environment, and effective stress regulation within this social context as indicted by a reduced adrenocortical response.

Heart Rate Variability (HRV), the fluctuation of instantaneous heart period over time, has been employed as the primary measure of cardiac autonomic regulation in social environments (Appelhans & Luecken, 2006). Greater variability represents increased vagal outflow to the sinoatrial node, where heart rate is regulated. Greater vagal influence results in rapid variation from cardiac cycle to cardiac cycle and is related to effective social engagement (Porges, 2011). HRV is commonly operationalized as an estimation of respiratory sinus arrhythmia (RSA), an index of HRV ordinarily based on the variation in R-R intervals derived from an ECG associated with respiratory patterns of inhalation and exhalation (Bernston et al., 1997). RSA indexes the level of myelinated vagal control of the heart, with higher RSA related to greater vagal control (Bernston et al., 1997).

HRV appears to be acutely impacted by social interaction environments. For example, the deficits in baseline HRV of depressed patients relative to controls are reversed when those patients become socially engaged in interactions with partners, family members or friends (Schwerdtfeger & Friedrich-Mai, 2009). Tasks that involve halting the natural progression of a social interaction, such as the still face procedures and the strange situation task, lead to a reduction in HRV (Conradt & Ablow, 2010; Hill-Soderlund et al., 2008; Moore, 2009).

The impact of social engagement and disengagement on HRV during social interactions could provide an important marker for social functioning and well-being. The inability to suppress RSA in children has been associated with higher levels of peer conflict when parenting involves a hostile-withdrawn style (Leary & Katz, 2004). Further, associations with high levels of facial expressivity and high vagal tone have been found in pre-schoolers (Cole, Zahn-Waxler, Fox, Usher, & Welsh, 1996).

Interestingly HRV appears to be a differentiating factor between children with social dysfunction disorders compared to typically developing children. HRV in children with autism may be reduced compared to control children (Bal et al., 2010; Graveling & Brooke, 1978). Apparent possible causes of this include blunting of autonomic responses to visual and auditory social stimuli (Palkovitz & Wiesenfeld, 1980). Some researchers have hypothesised that the social engagement system differs in individuals with social dysfunction disorders (Porges, 2007) and hence further differences during engagement and disengagement tasks may occur in individuals with social difficulties.

The aim of this study was to explore whether HRV provides a useful marker that differentiates between social engagement and disengagement in childhood. We expected HRV to remain at levels comparable to baseline during tasks that elicit social engagement, as a calm physiological state, indexed by higher HRV, facilitates social engagement. We further expected that HRV would be reduced during disengagement. In a task where both disengagement and engagement was present, we expected immediate reductions in HRV following disengagement that would be restored upon re-engagement. In contrast, we predicted that children at risk or with diagnoses of psychopathology would not show autonomic flexibility in social interaction tasks. That is, we hypothesised that children would not show distinct changes in physiology between social engagement and disengagement tasks. To confirm whether findings were specific to dyadic interactions, not a failure of HRV to respond overall, we examined HRV responses on the Trier Social Stress Task (TSST), a non-dyadic social stress speech task (Kirschbaum, Pirke, & Hellhammer, 1993). We predicted that the risk/diagnosis cohort would not show significant differences in HRV during dyadic tasks relative to baseline as these tasks rely on dyadic social interaction, a deficit skill in many social disorders. However during the TSST we expect differences in HRV relative to baseline would be present in the risk/diagnosis group as this task does not rely on social interaction skills.

Methods and Materials

Search methods for identification of studies

Initial search

The initial search was conducted on 31st of January 2013. The search strategy followed guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher, Liberati, Tetzlaff, & Altman, 2009).

Electronic databases including PsycINFO, PubMed/MEDLINE and EMBASE were searched using combinations of the following: *social, dyadic, interaction, synchrony, heart rate variability, respiratory sinus arrhythmia, vagal*. Databases were searched using the following terms: (Social[All Fields] OR Dyadic[All Fields] OR ("Interaction"[Journal] OR "interaction"[All Fields]) OR Synchrony[All Fields]) AND ((("heart rate"[MeSH Terms] OR ("heart"[All Fields] AND "rate"[All Fields])

OR "heart rate"[All Fields]) AND variability[All Fields]) OR (respiratory[All Fields] AND ("arrhythmia, sinus"[MeSH Terms] OR ("arrhythmia"[All Fields] AND "sinus"[All Fields]) OR "sinus arrhythmia"[All Fields] OR ("sinus"[All Fields] AND "arrhythmia"[All Fields]))) OR vagal[All Fields]). In addition to these electronic searches, each report's citation list was examined for additional studies. Reference lists of relevant review papers identified in the literature search were also examined for relevant references. Only studies that were reported in English were included in this search.

Data collection

The search strategy involved screening titles and abstracts for duplicates and identifying ineligible studies. Two independent reviewers (DSQ and SS) reviewed full text articles and any discrepancies were resolved via discussion. Relevant statistics were then extracted from the eligible studies by SS in the form of means and standard deviations, however one study provided an F statistic (Skowron et al., 2011), and these were included in the meta-analysis. During the process of analysis statistics were randomly crosschecked with those in papers by a second author (DSQ) to ensure consistency.

Criteria for considering studies for this review

All studies evaluating RSA during social tasks in children were included. All studies examined RSA as explicitly measured during performance of differing phases of task or task types. Only studies that were peer reviewed were included, which excludes the grey literature (e.g. dissertations) for the reason that the studies obtained appeared to be of a lower quality. However, some research has suggested that the exclusion of this literature can lead to an over-estimation of effect size of up to 15% (McAuley, Pham, Tugwell, & Moher, 2000).

Inclusion and Exclusion criteria

Participants included in this review were either (a) children recruited as healthy controls who were reportedly free from both mental illnesses and physical illnesses that could affect the respiratory system or (b) children characterized as being at risk or with a diagnosis for psychopathology (see Table S1 for details). These included risk for externalising problems as defined by classification on the Child Behaviour Checklist (Blandon, Calkins, Keane, & O'Brien, 2010) or children who may be at risk for insensitive parenting based on the Screening Scale for Problems in Parenting (Conradt & Ablow, 2010). Other included studies were those that reported on children with a diagnosis of autism spectrum disorder (Levine & Sheinkopf, 2012) or social phobia (Schmitz, Krämer, Tuschen-Caffier, Heinrichs, & Blechert, 2011) according to the DSM IV criteria. Studies were restricted to those that considered infants and children (i.e., 0-12 years) because social tasks used with these participants are comparable.

Types of Tasks

All dyadic social tasks were included where the participant and another individual (either the experimenter, confederate or parent) interacted with the child. Researchers have employed various experimental paradigms to study infant engagement and responsiveness during social interactions.

<u>Baseline Tasks:</u> The control condition used across studies requires participants to sit as still as possible with their eyes open for a short period of generally 5 to 15

minutes (Hastings et al., 2008). Some studies presented included baseline tasks where children were watching movies or observing toys in order to ensure they kept still.

The Still Face Procedure: In this procedure, a parent and child interact freely for several minutes. The parent then abruptly disengages from her child and maintains an expressionless 'still face' during the still face phase. Following this, she re-engages with the child, alleviating distress (Tronick, Als, Adamson, Wise, & Brazelton,., 1979).

The Strange Situation: During the procedure, the child's behaviours are observed during a period of free-play. After this, there is an entrance by a stranger, two periods of separation from the parent and finally reunion with parent (Ainsworth & Bell, 1969).

Dyadic Teaching Tasks: These require either a parent or experimenter to teach their child in an interactive and dyadic fashion. Tasks may include solving puzzles such as LEGO® DUPLO® puzzles, shape sorting puzzles and tracing tasks to encourage social collaboration and social engagement (Calkins, Graziano, Berdan, Keane, & Degnan, 2008; Skowron et al., 2011).

Free Play: These interactions involve the parent playing with their children as 'they normally would do during some free time on a typical day' (Moore et al., 2009). Some interactions involve using children's own toys, supplied by the parent (Feldman, 2003), others involve standardised sets of toys provided by the experimenter (Calkins et al., 2008), and in some there are no toys present (Feldman & Eidelman, 2007).

The Trier Social Stress Task: This task requires the active performance of a public speaking and mental arithmetic tasks in front of an audience who provide no feedback. This task has demonstrably induced social stress and increases cortisol (Het, Rohleder, Schoofs, Kirschbaum, & Wolf, 2009) but does not involve dyadic interaction.

Primary outcome measures

While we allowed for the inclusion of all measures of HRV, all studies that were found in our search for this quantitative synthesis used RSA as their central dependent measure, indexing vagal tone. RSA was extracted from an ECG trace in all studies (for details see Table S1).

Standard practice for extraction and analysis with RSA requires distribution be inspected for normality and in cases where normality assumptions are not met RSA is commonly log transformed to ensure the statistic is normalized (Riniolo & Porges, 2013). The parametric assumption of normality accompanying Hedges' g is unlikely to be violated with RSA as an outcome measure. Most studies used the Porges' (Porges, 1985) method for extracting RSA or the Grossman (Grossman, 1983) Peak-Valley technique, while some used the frequency band pass method or complex demodulation (details in Table S1).

Study Characteristics

Eighteen articles met our inclusion criteria from a total of 5944 studies (see Figure 1, outlining the number of papers included and excluded at each stage of the meta-analysis). These included eighteen independent studies and comprised 1544 research participants. The average number of participants per study was 86; details of these studies are provided in Table S1, available online.

[FIGURE 1]

Data Analysis

The Comprehensive Meta-Analysis (CMA; (Borenstein, Hedges, Higgins, & Rothstein, 2005) program was used to transform results of individual studies into the common metric of Hedges' *g*. Hedges' *g* was used as a measure of the standardized difference between intervention and control condition that corrects for biases that can lead to overestimation of standardized mean difference in small samples (Borenstein, Hedges, Higgins, & Rothstein, 2009). This effect size can be interpreted in the same way as Cohen's *d,* 0.2 represents a small effect, 0.5, a medium effect and 0.8, a large effect (Cohen, 1988).

To determine whether any publication bias was present Egger's regression test (Egger, Davey Smith, Schneider, & Minder, 1997) was used and the *p* value inspected for evidence of publication bias at $p<0.05$. The Cochrane handbook (Higgins & Green, 2011), providing a gold standard for quality of meta-analyses, advises against using this test where $n<10$ as the statistical power may be too low. In cases where this consideration was relevant we inspected funnel plots manually but acknowledge that future works are required to clarify the role of publication bias in these specific cases.

A series of meta-analyses comparing task to baseline effects were conducted. Firstly we compared engaging tasks to baseline and disengaging tasks to baseline. Following this we compared the disengaging still face phase of the still face procedure to baseline and reunion phases separately. RSA responses to free play and teaching tasks relative to baseline were also conducted, followed by a comparison of responses during the TSST relative to baseline.

Results

A summary of all results presented can be found in Table S2. In all results presented here the pattern of findings in the 'overall' cohort is consistent with those in the group that were assumed to be free from risk or diagnosis of pathology and hence are only presented once.

Engagement and Disengagement

The following analysis involves grouping tasks into categories depending on whether they induce social engagement or social disengagement. Social engagement tasks included the free play, teaching tasks and reunion with the parent or caregiver. Disengagement tasks included the still face phase of the still face procedure and the separation phases of the strange situation.

When statistics that represented social engagement were grouped together and compared to baseline RSA the result was non-significant (n=21, g=-0.111, p=0.541, 95% CI -0.467, 0.245) indicating RSA did not change during engagement tasks compared to baseline. During disengagement tasks, however, there was a significant decrease in RSA compared to baseline (n=8, g=-0.173, p=0.001, 95% CI -0.276, -0.071). Egger's regression test revealed there was no significant publication bias among studies used (p=0.698) and given n<10 we further inspected the funnel plot visually, however found no evidence of publication bias..

In order to explore whether there were differences in groups at risk or with diagnoses for psychopathology we conducted a further moderator analysis. Children at risk or with diagnoses for psychopathology showed no significant differences between RSA during engagement compared to baseline (n=8, g=-0.380, p=0.331, 95% CI -1.145, 0.386). Children at risk or with diagnoses for psychopathology did not show significant differences in RSA during disengagement tasks compared to baseline (n=1, g=-0.008, p=0.959, 95% CI -0.297, 0.282).

The next set of analyses set out to clarify the heterogeneity in the tasks classified in the broad categories of engagement and disengagement in the previous analysis. Here comparisons of each task to baseline were conducted individually and where applicable moderator analysis used to explore physiological responses in risk and diagnosed children.

Still face procedure

This is the only type of task with statistics available to us where engagement and disengagement was conducted on a temporal course.

Baseline and Still Face phase

Here we examine disengagement compared to baseline to see if there are any effects on HRV. When baseline and still face phase were compared overall, there was a significant difference found in RSA responses suggesting RSA was lower in the still face phase compared to baseline (n=7, g=-0.163, p=0.005, 95% CI -0.275, -0.050). Egger's regression test indicated no significant publication bias among studies used (p=0.278) and given n<10 we further inspected the funnel plot visually, however found no evidence of publication bias.

In order to explore whether there were differences in groups at risk or with diagnoses we conducted a further moderator analysis. In children at risk or with diagnoses there appeared to be no differences in RSA between the still face and baseline conditions (n= 2, g=0.012, p=0.919, 95% CI –0.228, 0.253).

Still Face Phase and Reunion

Then we compared re-engagement after a period of still face to see if there are any effects on HRV. A comparison of RSA during the still face phase and reunion conditions in children overall revealed a significant difference suggesting RSA is higher during the reunion phase than the still face phase (n=8, *g*=0.386, *p*=0.012, 95% CI 0.085, 0.687). Egger's regression test indicated there was evidence of significant publication bias (p=0.027), however the classic fail-safe N statistic indicated another 45 statistics would need to provide results contrary to those found in the present 8 statistics order to invalidate the finding.

In order to explore whether there were differences in groups at risk or with diagnoses we conducted a further moderator analysis. In children classified as at risk or with diagnoses there was no difference between the still face phase and the reunion phase of the still face procedure (n=1, *g*=0.000, *p*=1.000, 95% CI -0.298, 0.298).

Baseline and Reunion

In this part of the analysis we compare reunion to baseline to see if HRV returned to baseline levels or improved on baseline levels upon reunion with the caregiver. RSA change in the reunion phase of the still face procedure compared to the baseline phase was non-significant in children overall (n=3, *g*=0.123, *p*=0.224, 95% CI –0.075, 0.322). Egger's regression intercept revealed no evidence of publication bias (p=0.441).

In order to explore whether there were differences in groups at risk or with diagnoses we conducted a further moderator analysis. In children classified as at risk or with diagnoses there appeared to be no differences in RSA during reunion compared to baseline (n=1, *g*=0.000, *p*=1.000, 95% CI -0.289, 0.289).

Other Tasks

Teaching Tasks

An analysis of differences in RSA during teaching phases and baseline phases revealed that there were no significant physiological differences overall (n=5, g=-0.244, p=0.350, 95% CI -0.755, 0.268).

Free Play

An analysis of differences in RSA between baseline and free play conditions revealed that there were no significant physiological differences overall (n=12, g=-0.281, p=0.338, 95% CI -0.857, 0.294).

TSST

A comparison of baseline and the trier social stress speech task revealed a significant difference in RSA between these two conditions in children overall (n=4, g=-1.062, p<0.001, 95% CI -1.376, -0.747) suggesting RSA was lower during the stressful speech task than the baseline condition. Egger's regression intercept indicated there was no significant publication bias in these studies (p=0.891) and given n<10 we further inspected the funnel plot visually, however found no evidence of publication bias.

In order to explore whether there were differences in groups at risk or with diagnoses we conducted a further moderator analysis. Children at risk or with diagnoses appeared to have significantly different RSA during the TSST compared to baseline (n=2, g=-0.945, p<0.001, 95% CI -1.366, -0.545) indicating RSA decreased during the TSST.

Discussion

This study assessed the effect of social engagement, disengagement and non-dyadic social stress on HRV in young children. The results suggest that social engagement tasks in children do not alter HRV, but social disengagement results in a significant reduction (*g*=-0.173). We also evaluated HRV through the temporal course of social disengagement and re-union (re-engagement), showing that social disengagement led to a reduction in HRV, while reunion (social re-engagement) increased HRV back to baseline levels. We then evaluated the impact of child psychopathology or risk of psychopathology. This sub-group did not show autonomic flexibility indexed by HRV across social contexts. Finally, we evaluated the effects of a non-dyadic social stress task, the trier social stress task, on HRV in children with and without psychopathology. We found this task to have a very large effect (g = 1.06) on children, regardless of psychopathology (see Figure 2). Overall, results suggest that the impact of child psychopathology on autonomic flexibility appears specific to dyadic social stress tasks. This suggests that the reduced HRV during dyadic social interactions could represent an important biomarker for psychopathology given its absence in a context specific dyadic interaction for those at risk or diagnosed with psychopathology. Our measure of publication bias for all the results was non-significant indicating that it is unlikely that this type of bias was affecting our measure of effect size in these analyses.

[FIGURE 2]

Findings from this study indicate that social engagement does not increase HRV in children relative to baseline. Anatomically, the influence of the vagus on heart rate has been modelled as a braking mechanism (Porges, 2003) in which the myelinated vagus acts to slow the heart rate during periods of relaxation or rest. During social engagement and baseline conditions children are likely to experience relaxation and rest, which is associated with high vagal tonicity. The social engagement system, consisting of the muscles of the face, larynx and pharynx, and head, is primed in periods of rest or relaxation for social engagement and interaction (Porges, 2007), and our study therefore confirms that there were no differences present between these conditions.

Distinct decreases in HRV were demonstrated during social disengagement tasks. A possible explanation for this is that distress associated with disengagement leads to an inhibition of the vagal brake on heart rate (Porges, 2003). Polyvagal theory predicts that reductions in the influence of the myelinated vagus are associated with increases in activity of the sympathetic nervous system in order to support adaptive responses to stress (i.e., fight-flight behaviours). Certainly, behavioural responses of children during the still face procedure, including loss of postural control and vocalisations of distress, indicate that children partaking in this procedure were experiencing a significant amount of stress and employing self regulatory coping strategies (Ham & Tronick, 2006). Future studies examining both the cortisol response and the HRV of children during disengagement could confirm whether reduced tonicity of the myelinated vagus is correlated with increased sympathetic and adrenal activation, marking a fight or flight response.

Across all dyadic social interaction tasks, children who were categorised as at risk or with a diagnosis for psychopathology showed no differences in vagal tone during the task relative to baseline. Specifically these children demonstrated no changes in vagal tonicity during dyadic tasks or groupings of tasks; engagement, disengagement, still face phase or reunion relative to baseline. This meta-analysis therefore shows dysregulation of HRV in response to varied social contexts, in comparison to healthy control participants. Interestingly, this was not due to poor vagal response to other stressors, since the TSST resulted in similar responses regardless of whether the children were at risk or diagnosed with psychopathology. Therefore, the present study highlights the unique role of cardiac autonomic regulation in social interactions.

[FIGURE 3]

The effect size we obtained for our analysis of the TSST was sizeable (g=-1.062). The effect size we obtained for a parallel study conducted in adults was around a third of this magnitude (Shahrestani, Stewart, Quintana, & Guastella, 2013). Younger participants have far greater variance in HRV (Umetani, Singer, McCraty, & Atkinson, 1998) and hence this index is expected to be more sensitive in children. However, it is also possible that children may find the TSST more stressful than adults. Aging has been associated with a markedly reduced heart rate stress response and adrenocorticotropic hormonal response to the TSST (Kudielka, Buske-Kirschbaum, Hellhammer & Kirschbaum, 2004). This suggests that HRV reactivity to the stress of the TSST may be higher in younger participants and this decreases with age.

Future studies could combine behavioural measures such as eye gaze, posture or facial expression to assess how HRV changes based on the degree of engagement. Further, they could also explore the performance of participants in different diagnostic groups with psychopathology to allow comparisons to be made. Future studies could also clarify whether there are significant differences between children at risk for psychopathology and those with diagnoses and whether there may be predictive value in HRV assessments for clinical outcomes in these groups. By accessing a larger literature base future meta-analyses will be able to clarify any power issues that may have led to null findings in the present work and perhaps provide a more in depth quality appraisal of works.

Conclusion

Results from this meta-analysis suggest that social disengagement and re-engagement causes a distinct HRV pattern, whereby HRV decreases below baseline before increasing back to baseline levels. Interestingly, children with psychopathology did not show the same physiological responses as typically developing children. This suggests that atypical HRV responses could be used to identify social dysfunction and psychopathology in children, and may be a useful marker of effective social regulation.

Acknowledgments

This manuscript was partly supported by an Australian National Health and Medical Research Council project grant 1043664 to Guastella.

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Tables and Figures

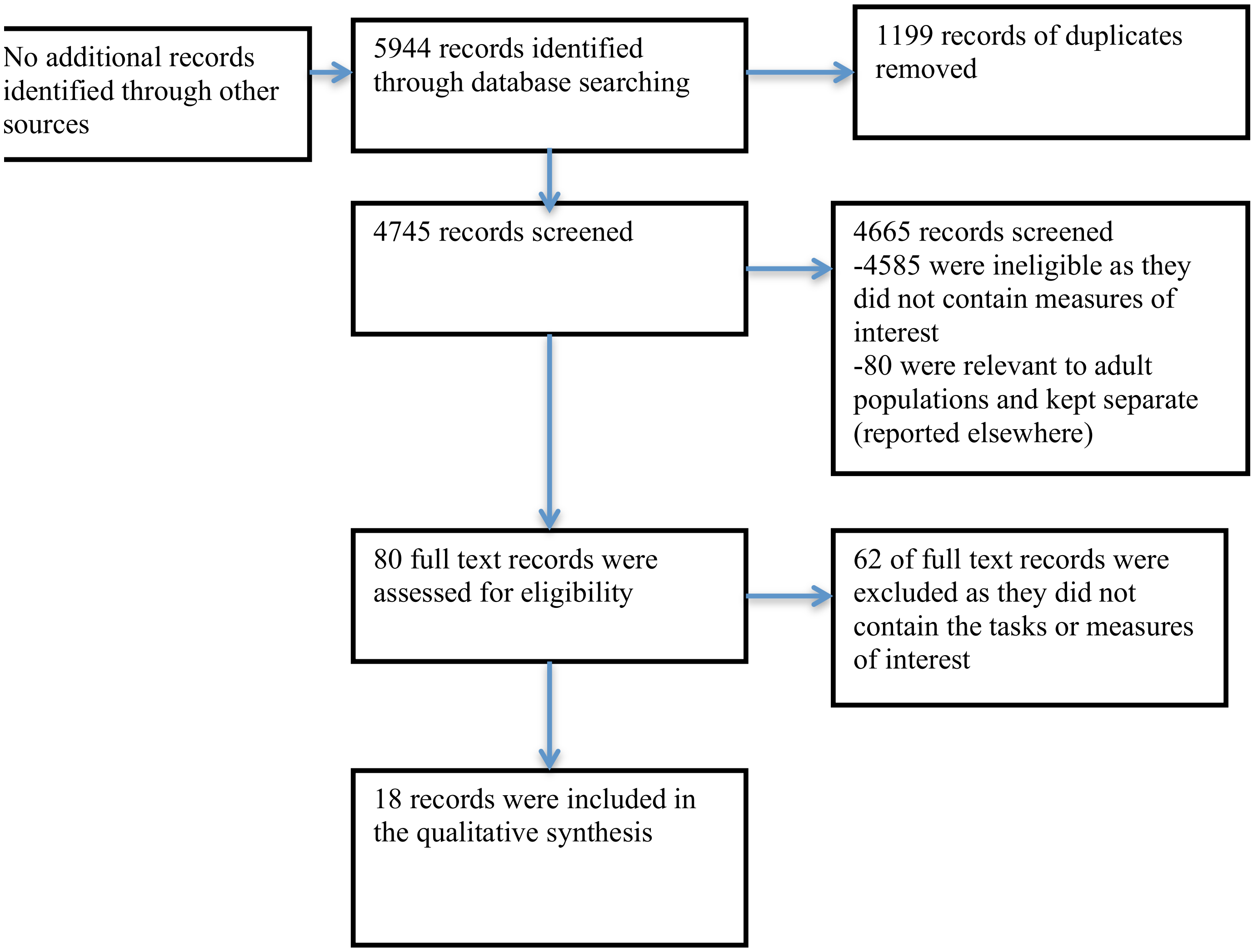

Figure 1. CONSORT diagram outlining number of papers included at each stage of the meta-analysis.

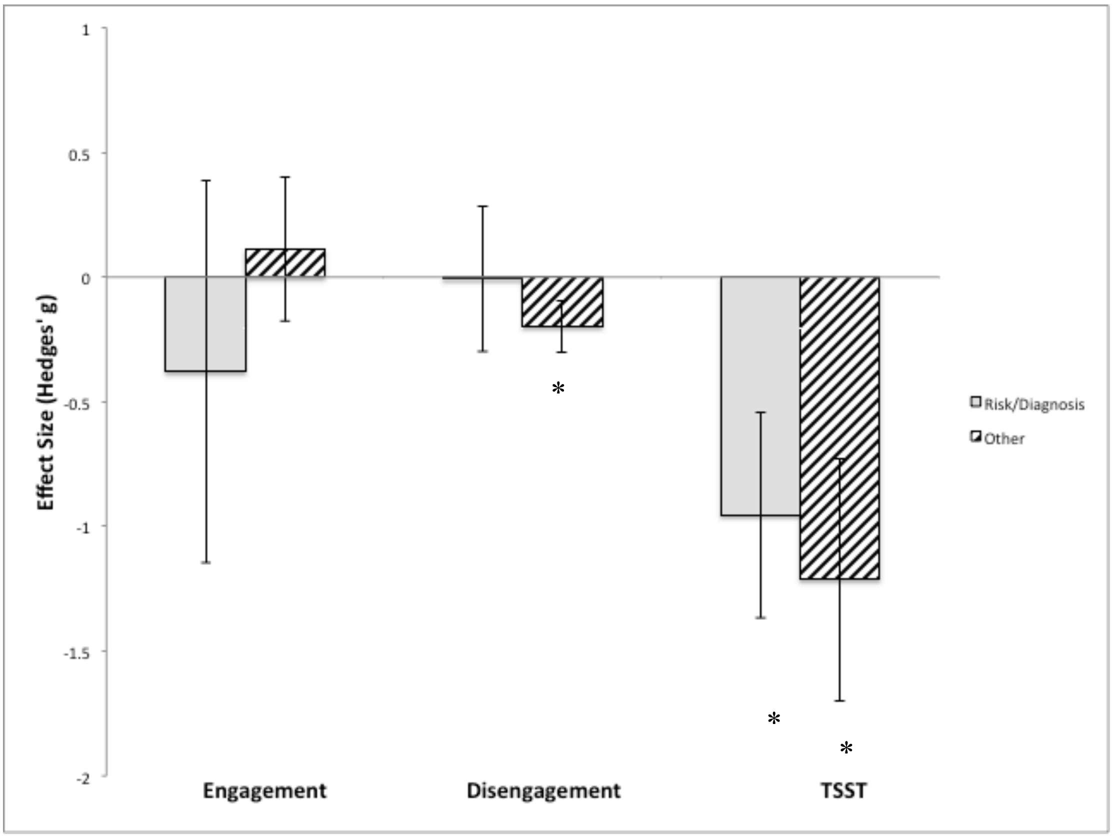

Figure 2. HRV responses in risk/diagnoses and overall cohort for engagement, disengagement and TSST. Error bars represent 95% confidence intervals and asterisks indicate significant results.

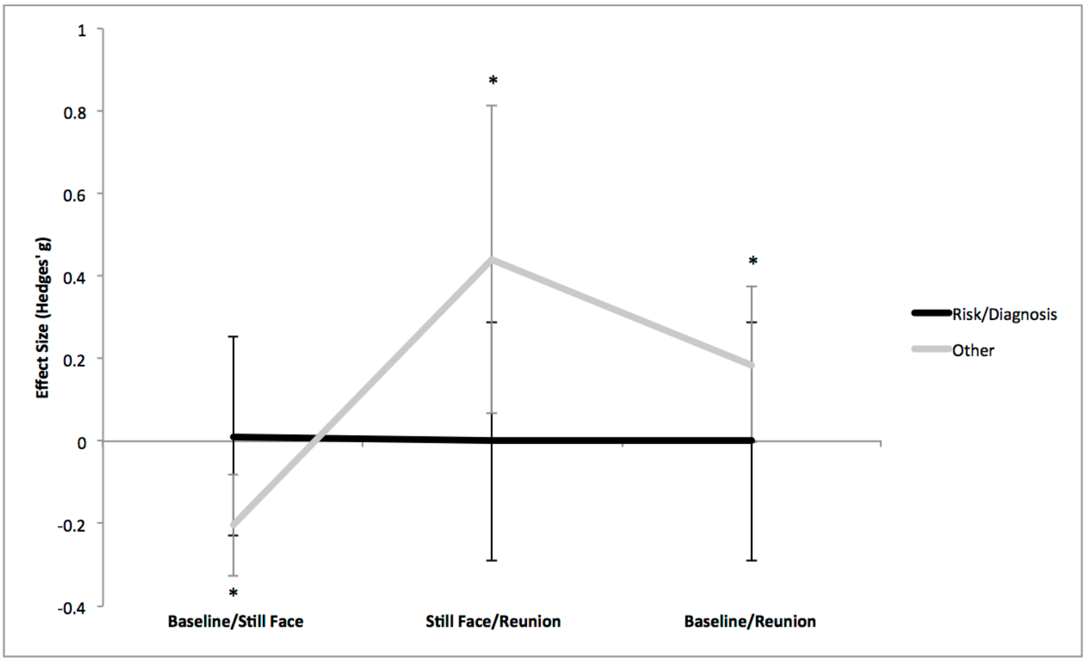

Figure 3. Effect sizes for comparisons of phases of the still face procedure in overall and risk/diagnosis for psychopathology groups. Error bars represent 95% confidence intervals and asterisks indicate significant results.

Key Points

- Disengagement from social interaction significantly reduces HRV relative to baseline
- Reunion after disengagement in the still face procedure restores HRV to baseline levels
- Children with risk/diagnosis for psychopathology have no HRV changes from baseline during any dyadic social tasks
- The TSST significantly reduces HRV in both the overall cohort and in the psychopathology/risk group. This shows that a reduced autonomic reactivity in the psychopathology/risk group is specific to dyadic interaction and not a failure to respond generally.