

Skin Conductance Synchronization Among Family Members: A Systematic Review

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Abstract. Physiological synchronization has often been associated to empathy. Several investigations are present in psychotherapy research, which show a link between attachment and Skin Conductance Synchronization (SCS). Surprisingly, scarce number of investigations deepened the phenomenon of SCS in family research. Our first aim was to delineate the state of the art of SCS studies among family members. A systematic review has been carried out in accordance with PRISMA guidelines on Scopus and Web of Science online databases. Only eight studies were retrieved that applied SCS measures to parent-child dyads (infants and adolescents) and marital couples. As a second aim, interpretations and future possible applications – based on past psychotherapy research findings and present results – are discussed.

Keywords: Skin Conductance Synchronization (SCS); Interpersonal Physiology (IP); embodiment; family; systematic review.

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Introduction

The study of Interpersonal Physiology (IP) – and of psychological dimensions underlying it – is experiencing a period of intense vitality in the scientific panorama involving, however, only some restricted areas of psychological research. More in detail, it seems that IP is a field of investigation still neglected in the context of family research, while an opposite trend is detectable in psychotherapy research where IP studies have flourished since the middle of the last century. The aim of our work is precisely to deepen the apparent lack of interest in this field of investigation in the context of family research studies.

Namely, the success of IP study has its roots in vicissitudes related to the history of psychotherapy research. The crucial debate on psychotherapy efficacy, epitomized as the “Dodo bird verdict” (Wampold et al., 1997) – according to which all psychotherapies, regardless of orientation or specific intervention strategies, yield roughly equal outcomes in patients – has radically changed the focus of psychotherapy research from the ‘90s onwards. As a matter of fact, scientific attention has almost completely shifted from outcome-focused research to process-focused research, reinvesting therapeutic relationship of its core role in the successfulness of the treatment (Norcross & Wampold, 2011). At the same time, it’s worth to be noted that the conception of psychotherapy as relational dimensions has gradually moved away from the idea of only two interacting minds, assuming, in an embodied perspective, the central role of the body in interpersonal actions as a complex resource for meaning making (Farnell & Varela, 2008).

This historical change towards the interpersonal and somatic dimension of therapy has been reflected, among other things, in a growing interest in interpersonal synchronization dynamics, both in terms of behavioral synchrony (e.g., Beebe et al., 2016; Paulick et al., 2018; von Zimmermann & Richardson, 2016) and in terms of synchronized physiological activity. In this regard, increasingly evidence indicates that knowledge of the physiological activity, detected in patient-therapist dyads, and of the physiological correlates of therapy process variables has the potential to provide unique insights into how and why psychotherapy interventions work (Deits-Lebehn et al., 2020). Of note, interest in IP dynamics has found fertile ground in social psychology research too, context in which interpersonal synchronization dynamics between teammates was detected as predictive in terms of group performance and cohesion (Henning & Korbela, 2005; Järvelä et al., 2013).

Physiological patterns of interpersonal synchronization are typically referred to as Physiological Synchronization (PS), i.e., the interdependence or

association identifiable between physiological activity of two or more individuals, mainly in terms of covariation in persons' physiological signals during interactions (Palumbo et al., 2017).

From a methodological perspective, research on counselling's and psychotherapy's PS dynamics has been mainly performed through the simultaneous collection of continuous indexes of the autonomic nervous system.

Specifically, skin conductance (SC), the method of choice to measure electrodermal activity, is the elective index used for the investigation of human relational dynamics because of the ease of its application in an ecologically valid manner – in addition of its non-invasiveness – and for the facility of acquisition, analysis and interpretation of its signal (Boucsein, 2012).

From an underlying construct perspective, past studies on clinical Skin Conductance Synchronization (SCS) suggest – partially in line with social psychology research's findings – that synchronization patterns between patient and therapist during therapeutic exchanges are associated to states of empathic attunement (Marci et al., 2007; Marci & Orr, 2006; Marci & Riess, 2005; Robinson et al., 1982) and are strictly connected to the outcome of the treatment (Kleinbub et al., 2019), given that empathy is traditionally considered a predictor of outcome (Orlinsky et al., 1994). More specifically, the ways in which SCS dynamics are realized in therapeutic exchanges seem to be mediated also by attachment security (Kleinbub et al., 2020; Palmieri et al., 2018). In detail, SCS was found to be affected by therapist's exposure to a sense of attachment security prime (Palmieri et al., 2018), as well as significant levels of SCS in the clinical setting have been found during interactions associated with attachment security (Kleinbub et al., 2020).

In particular, regarding our aims, it's worth to be noted that analogous implications of synchronization phenomena in the development of child's attachment system, and in its subsequent reactivation, had already been suggested by Beebe and Lachmann (1994, 2002), according to which the building of infant's internal working models of attachment would be strongly influenced by dynamics of co-regulation and synchronization – on both behavioral and psychophysiological levels – active between mother and child.

Getting to the core of our investigation aims, it is a fact that IP research is still on its infancy as evidenced by the absence in literature of a clear and shared terminology to refer to it (Kleinbub, 2017; Palumbo et al., 2017). In particular, once again, family, as primary context of development and reactivation of the attachment system, seems to be groundlessly neglected

from PS investigation.

In this regard, our first aim is to carry out a fine-grained analysis about the state of the art of SCS studies among family members which includes all possible keywords, in a systematic review conducted in accordance with PRISMA guidelines – as they are among the most widely acknowledged criteria in drafting systematic reviews (according to Equator Network [<https://www.equator-network.org/>] or Siddaway et al. [2019], for example). We chose to focus our attention on articles about SCS dynamics in order to shed light on a phenomenon, SCS, able to investigate relationships via little invasiveness and high ecology, as stated above (Boucsein, 2012).

Furthermore, SC is a reliable and precise index of autonomous nervous system activation in its sympathetic branch only, contrarily to other measures of autonomous nervous system activation that detect both sympathetic and parasympathetic activity (e.g., heart rate variability; Cacioppo et al., 2007).

The sympathetic system is traditionally related to the arousal dimension of emotional experience (Sequeira et al., 2009), while the parasympathetic system is also associated to resting, feeding, and sexual arousal, and modulates also cognitive and attentional processes (Smith et al., 2017).

For this reason, the selectivity of SC in detecting only sympathetic activity leads the data present in literature – and data of papers considered in our review as well – to be more unambiguously interpretable. Finally, selective results on SCS allow us to compare them among themselves and to those of psychotherapy research findings.

As second aim of our paper, we intend to delineate working hypotheses and discuss application proposals on the basis both of past findings – mainly on florid psychotherapy research and attachment-related investigations – and our systematic review results.

Methods

Search strategy. Our systematic search strategy is in accordance with PRISMA guidelines (Moher et al., 2009). A systematic research of online databases using key phrases was conducted to identify studies published from January 1st, 1970 to July 30th, 2020, quantitatively assessing physiological synchronization among family members. Literature search was performed in Scopus and Web of Science (core collection) online databases, given that they are considered two of the most accredited databases in international scientific research (Guz & Rushchitsky, 2009).

Three sets of keywords were chosen to identify the pertinent papers: a first

set assessing the subject of synchronization (synchron*, concordance, covarian*, attunement, linkage), a second set specifying the physiological nature (electrodermal, eda, galvanic skin response, gsr, skin conductance), and a third set specifying the familiar context (parent*, mother, father, bab*, toddler, infant, child*, adolescen*, spouse, marital, married, twin, sister, brother). A wildcard symbol (*) was employed to generalize those keywords typically characterized by varying suffixes (e.g., one paper might exclusively employ one of the forms “synchrony”, “synchronization”, or “synchronous”, the wildcard form “synchron*” would match them all). The search was performed by fixing a logical conjunction (AND) relationship between the three sets, this means that each result was required to have at least one member of each set. Search areas for Scopus included the “title/abstract/keywords” for the search terms. Last search was performed on July 31st, 2020. Appendix 1 reports the complete search string for both databases.

Selection criteria. The literature search and abstracts were reviewed for eligibility and only original research articles, written in English, and published in international peer-reviewed journals, were considered. All eligible articles underwent a second in-depth text inspection to check for the following inclusion criteria: considering familiar interactions and physiological synchronization was based on skin conductance. When considering dyads of partners, only married couples were included as marriage was used as a proxy for committed relationships. Duplication removal was performed with package revtools v0.4.1 (Westgate, 2019) for R software v4.0.2 (R Core Team, 2020). A criterion of inclusiveness was preferred to a quality one. The procedure is summarized in a PRISMA flow diagram (Fig 1).



PRISMA 2009 Flow Diagram

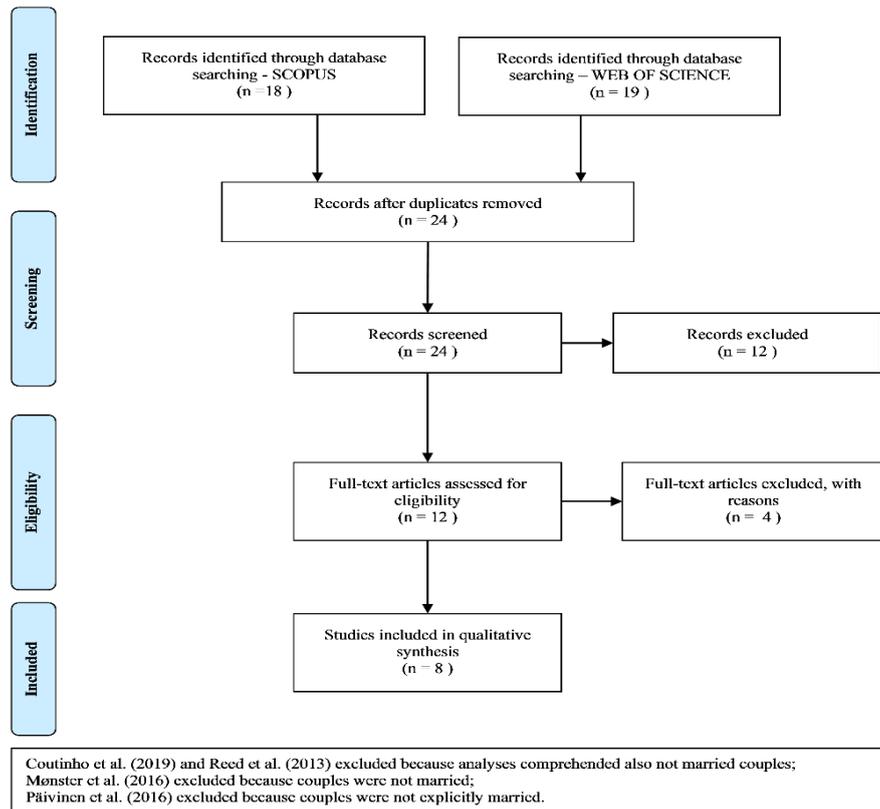


Fig 1. Flow diagram for qualitative systematic review of skin conductance synchronization in family members.

Results

A total of eight articles were retrieved following the bibliographic search. Two articles investigated exclusively the mother-child dyad; one article considered both mother-child and father-child dyads; one article focused on mother-adolescence dyads; one article investigated caregiver-child dyads (caregivers were not divided by sex); three articles investigated married couples. A summary of the results is presented in Table 1, where the relevant information was extracted by one author (Y.C.) from the retrieved articles: (a) type and number of participants; (b) purposes; (c) methods used; (d) main results.

Reference	Sample	Purpose	Procedure	Results
Parent-child dyad				
Baker et al. (2015)	28 primary caregiver-child (4-10 years) dyads	To examine SCS between parents and their child with autism spectrum disorder (ASD).	Following a 5-min baseline, dyads engaged in a 4-min prohibition task and in 4 min of free play while SC was recorded. An IQ assessment and a direct measure of autism symptoms in child were performed.	Strength of SCS was negatively associated with child's diagnosis severity. Lower ASD symptom levels were associated with stronger SCS.
Busuito et al., (2019)	140 mother-child (6 months) dyads	To examine interaction between SC and dyadic behavioral synchronizati on.	Following a 4-min baseline interaction, dyads participated in the face-to-face still-face paradigm while SC data was acquired, and behavior was video-recorded.	SCS was detected within all episodes of the still-face paradigm. Behavioral synchronization was not associated with SC in infants and mothers.
Ham & Tronick (2009)	18 mother-child (5 months) dyads	To examine SCS and behavioral synchronizati on in mother-infant dyads.	Dyads participated in the face-to-face still-face paradigm. SC and interactions' video were recorded. Mothers' and infants' behaviors were coded.	SCS correlated during the still-face paradigm with infant negative engagement. Upon mothers engaged in subsequent soothing of infants, SCS correlated with behavioral synchronization.
Lorang et al., (2020)	15 mother-child (2-5 years) and 15 father-child dyads (15 families)	To examine SCS between parents and their child with Down syndrome (DS) and the relation between parent and child SC and parent behaviors.	Dyads participated in a seven-minute recorded free play activity while SC was acquired. Parent's communication behavior coding was performed.	SCS was detected during father-child but not mother-child interactions. Maternal requests for child behavioral comply were positively related to child SC variability.
Mother-adolescent dyad				
Lougheed & Hollenstein (2017)	66 mother-daughter (14-17 years) dyads	To examine SCS in mother-daughter dyads across different emotion	Participants filled out some questionnaires about relationship closeness, then dyads were randomly assigned to two experimental conditions: in Touch condition	A global presence of mother-to-daughter arousal transmission (i.e., SCS) was detected, while daughter-to-mother arousal transmission

contexts during adolescence. participants were instructed to touch each other's hands, while in No Touch condition they were instructed to have no physical contact. Dyads participated in the following while SC was measured:

1. 2.5-min baseline.
2. 3 min of adolescent's speech on any topic as if in front of classmates at school (to elicit social stress).
3. 4 min of conversation about times they experienced negative emotions (embarrassed or anxious).
4. 4 min of conversation about times they experienced positive emotions (happy or excited).

was detected only in the context of physical contact in positive discussions for daughters who perceived greater relationship closeness.

Married couples

Laitila et al., (2019)	A married couple and two male psychotherapists.	To detect significant topical episodes by analyzing participants' SCS.	SC was detected in participants during a session of couple therapy. Then the session transcripts were investigated and divided into topical episodes using the Dialogical Investigations of Happenings of Change (DIHC).	SCS was detected between each therapist and one client during nonverbal interaction and between all participants after therapists' interventional moves.
Levenson & Gottman (1983)	30 married couples.	To examine whether SCS was predictive of couples' marital satisfaction.	Couples participated in the following while SC and video were recorded: <ol style="list-style-type: none"> 1. Low-conflict interaction: 5-min baseline then 15 min of conversation about their day. 2. Questionnaires. 3. High-conflict interaction: 5-min baseline, then 15 min discussing the problem area. 4. Video-recall: each spouse rates his/her own state during the original trials after watching video of their 	SCS was associated with lower marital satisfaction exclusively during high-conflict interactions.

		interactions.		
Thomsen & Gilbert (1998)	32 married couples.	To examine the interaction of self-reports, observations, and SCS in predicting couples' marital satisfaction.	Following a 5-min baseline, couples discussed a conflict topic for 15 min, while SC and video were recorded. They then completed questionnaires and rated their own states while watching video of their interaction.	During conflict discussions, SCS was detected between individuals with higher marital satisfaction whereas discordant SCS was more common in dissatisfied couples.

Table 1. *Relevant information of the retrieved articles.*

Discussion

As for the first purpose of our work, the present systematic review results confirm that poor and fragmented studies have emerged, testifying that SCS investigation in the field of family research still receives scarce attention in the scientific panorama, despite family represents a promising area for the study of interpersonal dynamics from an embodied perspective.

Moreover, regardless the scarcity of results, studies taken into consideration in this work appear so heterogeneous in terms of experimental paradigm, considered variables, sample and findings, that SCS meaning in this context remains of difficult interpretation. It seems a similar panorama to what was outlined until the '80s in psychotherapy investigation, when a paucity of researchers have devoted themselves to the topic, groping in the dark to interpret the meaning of PS dynamics in psychotherapy (Coleman et al., 1956; DiMascio et al., 1957; Di Mascio et al., 1955; McCarron & Appel, 1971; Robinson et al., 1982; Stanek et al., 1973).

More in detail, in the studies identified so far, two articles investigated mother-child interactions, using the still-face paradigm (Tronick et al., 1978). In the first one, Ham and Tronick (2009) collected data from mother-child dyads and described that SCS occurred in the still-face and in the reunion phases of the paradigm. This result seems only partially in accordance with the notion of empathy being important in psychotherapy for therapists above all to repair alliance ruptures (Safran et al., 2011). However, the same assumption does not find fulfilment in the results of Busuito and colleagues (2019) who, by repeating the same experimental paradigm in a very substantial sample, described SCS as present within all episodes of the still-face paradigm. These limited studies are therefore in contrast with the amount of studies of psychotherapy research, and suggest at the core of PS, instead of empathic attunement, a more complex – and still unknown – phenomenon.

Moreover, two studies investigated parent-child SCS in case of children

with syndromes, specifically Down syndrome (Lorang et al., 2020) and Autism Spectrum Disorder (Baker et al., 2015). Lorang and colleagues (2020) evaluated SCS both in mother-child and in father-child free play moments finding significant higher-level association of parent and child SC variability during father-child interaction. Such a result still remains difficult to interpret but – as the authors suggest – it could be a reflection of the mother’s different role in terms of regulating child’s behavior. On the contrary, a more immediate speculation is arguable about Baker and colleagues’ (2015) findings, which highlighted a negatively association between mother-child SCS and child’s autism diagnosis severity. In the field of psychotherapy research IP studies, Kleinbub and colleagues (2019), based on their findings, advanced the idea that the shared psychophysiological activation can represent an empathic somatic mirror mechanism. In parallel, dysfunctional simulation mechanisms, such as the mirror neuron system, seems underlie the social and communicative deficits seen in individuals with autism spectrum disorders (Oberman & Ramachandran, 2007). In this perspective, the diagnosis severity could reflect the dysfunction of the mirror mechanisms level and therefore manifest in lower SCS levels during child-mother interaction.

Only one study considered SCS among parent-adolescent interaction, specifically mother-daughter dyads (Lougheed & Hollenstein, 2017) detecting a mother-to-daughter arousal transmission. In our opinion, this effect of parental regulation and control appears particularly intriguing, suggesting interesting prospects for further investigations. In this regards we are persuaded that different pattern of lag SCS may be detectable among parents and adolescents with Oppositional Defiant Disorder or Conduct Disorder (ODD/CD) in front of family contexts typically characterized by cycles of coercion and abdication of parental control (Patterson, 1982).

As regards to married couples’ SCS during naturalistic interactions, two studies emerged from our systematic review. In the oldest of the two, Levenson and Gottman (1983) detected SCS in association with lower marital satisfaction when couples’ interaction revolved around topics of high conflict. Contrary to Levenson and Gottman’s study, Thomsen and Gilbert (1998) detected SCS during conversation about high-conflict topics, but in those with higher marital satisfaction. These seemingly conflicting results can be consistently interpreted in a speculative manner by reading physiological attunement as a reflection of the interactions’ engagement level, more than of circulating affects’ quality or contextual variables.

Finally, only one study assessed marital couples during psychotherapy with two therapists (Laitila et al., 2019). In this case-study, the authors detected SCS between each therapist and one client during nonverbal

interaction and between all four participants after therapists' interventional verbal exchanges. These extremely intriguing results suggest that latent alliances – such as a split therapist-client alliance – can be detected through the measurement of SCS and may change during treatment. From an analogous perspective, reproducing the present study in the even more complex setting of family therapy could reveal the presence of latent alliances even between subgroups of the family itself, becoming a highly informative tool in the therapeutic context. Furthermore, this study is the only one to propose an experimental design that overlaps psychotherapy and family, demonstrating the feasibility of an IP oriented approach in the context of couple and family therapy. This peculiar perspective will be dealt in more detail in the second part of our discussion.

In sum, the field of SCS research among family members shows paucity of studies and a greater heterogeneity in results compared to the parallel findings of IP investigation in psychotherapy research, also from methodological perspective. Furthermore, findings of our review's studies deviate strongly from those obtained in clinical settings, suggesting that, in the family context, SCS is more probably linked to a dimension of relational engagement, which does not always correspond to exchanges of empathic nature.

The second aim of our work is to advance proposals based on our review's findings. Since we have not found studies with stable paradigms in infant-parent interaction, nor with the simultaneous collection of physiological activity data in the context of the whole family, Lausanne Trilogue Play (LTP; Fivaz-Depeursinge & Corboz-Warnery, 1999) can represent, in our opinion, a particularly suitable paradigm for investigating family's SCS in a more complex and complete way. Specifically, LTP consists in an experimental paradigm for the observation and evaluation of family triadic interactions' quality. It includes four distinct moments of interaction involving respectively and sequentially one of the parents (in turn) with the child, the parental couple and all the three family members. Such a setting is particularly suitable for the collection of individual physiological data in order to fully evaluate dyadic SCS – considering at the same time physiological activity of the third member of the family – and triadic SCS. In parallel, in this kind of experimental paradigm, physiological measures assessment can be easily combined with additional relationship's qualitative and/or behavioral assessment tools, in order to formulate valid and complete interpretations of SCS phenomena.

From an attachment-related perspective, moreover, no SCS study has been conducted with paradigms specifically aimed at classifying infant's attachment style during parent-child interactions. In this regard, the Ainsworth

Strange Situation (Ainsworth et al., 1978) – i.e., a laboratory-based observation of the infants' response to two brief separations from, and reunion with, the parent – seems to be a suitable paradigm for our proposal. In fact, within this situation, infant behavioral responses are customarily classified as fitting to one of three overall patterns of attachment (i.e., secure, insecure-avoidant, or insecure-ambivalent/resistant). This kind of investigation, which combines SCS measures with attachment pattern's classification via Strange Situation, as well as being particularly intriguing in the context of attachment-related research, could further clarify the already known association between attachment security and SCS in psychotherapy.

From a clinical perspective, in light of the promising findings obtained within individual therapies – according to which SCS is associated with relational variables positively related to the outcome –, clarifying the meaning of SCS in the context of couple therapy – as well as more in general in family therapy – can offer a great contribution both in theoretical modelling and in guiding therapists in clinical practice. As suggested at several times, in fact, a useful application of IP in clinical practice consists in the implementation of psychotherapy training programs oriented towards an embodied perspective, e.g., with the use of interpersonal biofeedback techniques in order to inform psychotherapy trainees of moment-to-moment SCS dynamics (Gennaro et al., 2019; Kleinbub et al., 2020).

In such a direction, it would be interesting to introduce SCS investigation into systemic therapy research and practice. This field of investigation seems to be a fertile and already set up ground, since recordings have been a practice since the '60s in its methodological-theoretical framework (e.g., Mental Research Institute of Palo Alto provides therapy rooms equipped with a one-way window for observation and supervision and a microphone for tape recording [see Jackson & Weakland, 1961]).

Hence, family therapists could benefit from SCS training programs too, by learning on the one hand to modulate their own and others' physiological activation, on the other to recognize and attribute meaning to SCS moments among family dyads or within the whole family.

Despite the theoretical insights and applicative proposals emerged from this systematic review, some limitations should be taken into consideration. First, the fact that having adopted a conservative research method, with the exclusion of other online databases (such as PsycINFO, PEP-Web, etc.) has guaranteed the quality of our results and their scientific value (Guz & Rushchitsky, 2009). However, such a selective research direction could have undermined greater availability, leading to the exclusion of more educational publications that could be useful for theoretical reflections and comparisons.

Secondly, it should be noted that in this systematic review it was decided to embark on a well-defined research path, which provided for the inclusion of the IP studies based only on SC acquisition. Such a decision, although motivated from a methodological point of view, represents a limit since inevitably has led to exclude studies on family IP based on alternative physiological measures, such as cardiovascular (e.g., inter-beat interval, respiratory sinus arrhythmia, heart rate variability) or respiratory (e.g., respiratory rate, respiration volume time) measures. For example, cardiovascular measures, reflecting both sympathetic and parasympathetic nervous system activity, lead to more heterogeneous interpretation of data. Nonetheless, heart rate variability is an index of therapeutic improvement, which increases along successful therapy and consequent patient's well-being (Blanck et al., 2019). Thus, future discussions would benefit from focusing on other physiological indexes with interesting considerations that could emerge from the comparison between these interpretations and ours. Finally, the decision to consider only studies on marital couples, has allowed us to advance our speculation around SCS between committed partners, but leading us to exclude studies on committed but unmarried couples.

To conclude, our systematic review sheds light on a neglected area of SCS research, that is family, which however seems to have enormous development potential. In our opinion, further studies on family IP assume an extreme importance both for the empirical value of understanding the functioning of SCS, and for the heuristic value of reaching an understanding that goes beyond words in family clinical practice, once disambiguated the nature of family SCS.

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Appendix 1

Scopus

TITLE-ABS-KEY (((synchron* OR concordance OR covarian* OR attunement OR linkage) AND (eda OR electrodermal OR "skin conductance" OR "galvanic skin response" OR gsr)) AND (((parent* OR mother OR father) AND (bab* OR toddler OR infant OR child* OR adolescen*)) OR (spouse OR marital OR married) OR (twin OR sister OR brother))) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))

Web of Science

TOPIC ((synchron* OR concordance OR covarian* OR attunement OR linkage) AND (eda OR electrodermal OR "skin conductance" OR "galvanic skin response" OR gsr)) AND (((parent* OR mother OR father) AND (infant OR child* OR adolescen*)) OR (spouse OR marital OR married) OR (twin OR sister OR brother))