Developmental Cognitive Neuroscience 65 (2024) 101330

Contents lists available at ScienceDirect

Developmental Cognitive Neuroscience

journal homepage: www.elsevier.com/locate/dcn

It takes a village: A multi-brain approach to studying multigenerational family communication

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ARTICLE INFO

Keywords:
Multi-brain simulations
Grandparent-child interactions
Inter-brain coupling
Community neuroscience

ABSTRACT

Grandparents play a critical role in child rearing across the globe. Yet, there is a shortage of neurobiological research examining the relationship between grandparents and their grandchildren. We employ multi-brain neurocomputational models to simulate how changes in neurophysiological processes in both development and healthy aging affect multigenerational inter-brain coupling – a neural marker that has been linked to a range of socio-emotional and cognitive outcomes. The simulations suggest that grandparent-child interactions may be paired with higher inter-brain coupling than parent-child interactions, raising the possibility that the former may be more advantageous under certain conditions. Critically, this enhancement of inter-brain coupling for grandparent-child interactions is more pronounced in *tri*-generational interactions that also include a parent, which may speak to findings that grandparent involvement in childrearing is most beneficial if the parent is also an active household member. Together, these findings underscore that a better understanding of the neurobiological basis of cross-generational interactions is vital, and that such knowledge can be helpful in guiding interventions that consider the whole family. We advocate for a community neuroscience approach in developmental social neuroscience to capture the diversity of child-caregiver relationships in real-world settings.

1. Introduction

Numerous studies have demonstrated that everyday family interactions during childhood are crucial for lifelong happiness and health (Manning et al., 2019; Tanskanen and Danielsbacka, 2018; Favez et al., 2017; Tissot et al., 2015; Masarik and Conger, 2017). While the concept of the "nuclear" family generally evokes representations of a household with two parents and 2.5 children, grandparents – particularly grandmothers – play a critical role in child rearing across cultures. In fact, grandparents often act as the primary caregivers for children worldwide (Chen et al., 2011; Hank and Buber, 2009), with estimates suggesting that grandchild care constitutes one quarter of child care in the United Kingdom (Smith, 2002) and over 50% in China (Ko and Hank, 2014).

In the United States, the proportion of families residing in multigenerational households has been steadily increasing, rising from 14% in 1990 to 20% in 2016 (Cohn and Passel, 2018). For some, shifting to a multigenerational living situation may be necessary due to high rental costs and unequal access to stable housing. For others, it may be a way to offer support and improve cultural socialization. Although grandparents serve as caregivers to their grandchildren across all socio-demographic groups, the proportion of intergenerational households varies by race and ethnicity, with higher rates of multigenerational households among families of color (Cohn and Passel, 2018; Pilkauskas and Martinson, 2014). Hispanic families are often characterized by a strong sense of familism (Facio, 1996) and African-American grandparents have been reported to view their caregiving role as essential in strengthening cultural and support systems within their families (Wiscott and Kopera-Frye, 2000). Within Asian households, childrearing knowledge is highly valued and Asian grandparents view their role as helpful in the development of ethnic identity (Kataoka-Yahiro et al., 2004).

The few studies that have investigated grandparent-child relationships have shown that grandchild care may improve the mental and physical health of grandparents (Grundy et al., 2012). Studies have demonstrated that grandchild care leads to better self-rated health, fewer depressive symptoms, and better verbal fluency for grandparents (Arpino and Bordone, 2014; Ku et al., 2012). Grandparents may also influence child development both directly through interactions with the child (e.g., reading with the child, discussing emotions or behaviors, etc.) or indirectly through relationships with the child's parent (e.g., providing financial or emotional support). Indeed, the presence of

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https://doi.org/10.1016/j.dcn.2023.101330
Received 1 May 2023; Received in revised form 27 August 2023; Accepted 7 December 2023
Available online 12 December 2023

grandparents may impact the quality of parenting practices within households, and parent-grandparent co-parenting has been found to be positively associated with the parent-child relationship (Li and Liu, 2020). For example, Barnett et al. (2010) reported that grandmother involvement mitigates associations between maternal harsh parenting and child externalizing behaviors. Another study by Silverstein and Ruiz (2006) found that grandparents may buffer the transmission of maternal depression to children.

Across previous work, differences in family well-being emerge between grandparents having primary custodial care of grandchildren (i.e., when parents are not part of the child's life for various financial or legal reasons) vs. when grandparents co-reside with their grandchildren. In studies examining co-residence, there is evidence for grandparents strengthening grandchild communication skills (Cruise and O'Reilly, 2014), language development (Reynolds et al., 2018), and educational achievement (Deindl and Tieben, 2017; Perry, 2017; Pong and Chen, 2010). Within the U.S., these associations between grandparent co-residence and child outcomes may be moderated by immigrant status (Pilkauskas, 2014).

In sum, the literature highlights the importance of acknowledging the diverse family structures and cultural values in society, recognizing the vital role that grandparents play in child development, and understanding how multigenerational households affect families' well-being. Yet, developmental neuroscience research has largely focused on the mother-child relationship (but see Rilling et al., 2021; Kida et al., 2014), and to our knowledge, no studies to date have directly studied dynamic social interactions among tri-generational family members.

Below, we first offer a brief overview of recent advances in naturalistic neuroscience research focusing on social alignment and communicative outcomes, with a specific emphasis on inter-brain coupling, a neural marker that has been linked to a range of socio-emotional and cognitive outcomes. As past studies have demonstrated positive associations between parent-grandparent co-parenting and child relationships within the home (Li and Liu, 2020), we hone in on intergenerational communication and discuss key hypotheses related to inter-brain coupling and communicative outcomes in parent-child and grandparent-child interactions. Then, we present findings from multi-brain neurocomputational models simulating how widespread changes in brain systems that support cognitive functioning in both development and healthy aging impact multigenerational inter-brain coupling. Our simulations raise the possibility that grandparent-child interactions may be more in alignment than parent-child interactions under certain conditions, and that tri-generational interactions may be optimal for specific outcomes. We conclude by advocating for a deeper understanding of the neurobiological foundations of cross-generational interactions, which can inform interventions that incorporate the entire family. Further, we argue for a community neuroscience approach in developmental social neuroscience, in order to capture the diversity of child-caregiver relationships in real-world settings.

2. Neural alignment in children, adults, and grandparents

Prior work has primarily situated communication challenges *within* children and family members, largely ignoring interpersonal factors. In recent years, however, a growing number of studies have shown that alignment – also often referred to as *synchrony* – can be socially meaningful in a variety of modalities, including movement, language, neurophysiology, and pupil dilation (Pan et al., 2022; Nguyen et al., 2021); Wohltjen and Wheatley, 2021; Pickering and Garrod, 2021; Dikker et al., 2021b). Here, we focus on neural synchrony, or inter-brain coupling, which has been associated with a range of communicative outcomes, including language comprehension, socio-emotional connectedness, learning, and even pain perception (Goldstein et al., 2018; Dumas et al., 2010; Wass et al., 2020; Davidesco et al., 2023; for reviews see e.g., Czeszumski et al., 2022, 2020; Koike et al., 2015; Tsoi et al., 2022; Babiloni and Astolfi, 2014; Toppi et al., 2016; Liu et al., 2018; Nguyen et al., 2020; Reindl et al., 2018; Marriott Haresign et al., 2022).

Positive associations between interpersonal neurobehavioral synchrony and cognitive or socio-emotional outcomes have been observed at different timescales, ranging from immediate, to medium-term, to longer-term. In intergenerational contexts, for example, similarities in resting state brain activity between parents and their teenage children has been found predictive of everyday family interactions (Lee, Miernicki, and Telzer, 2017), and teacher-student inter-brain coupling during learning is linked to social closeness and lesson retention (Bevilacqua et al., 2019; Dikker et al., 2017; Davidesco et al., 2023). In infants and young children, biobehavioral synchrony has been suggested to predictive of developmental outcomes (Quiñones-Camacho et al., 2021; Feldman, 2007), but this link has yet to be investigated systematically (Noreika et al., 2020; Turk et al., 2022).

As summarized in Fig. 1, inter-brain coupling during real-time social events (as measured via *hyperscanning*) has been linked to stimulus entrainment (e.g., lectures, stories, concerts; e.g., Chabin et al., 2021) and joint social behavior (conversation, joint action (Pérez et al., 2017; Dumas et al., 2010; Konvalinka et al., 2014; Dikker et al., 2021b), which may be mediated by individual differences and contextual factors. These include personality traits, (social) engagement, mental states, the nature and quality of the relationship, priors, and, critically: individual neurobiological variation ("neural profiles"). For example, our work and that of others has found that inter-brain coupling between speakers and listeners is affected by sharing linguistic predictions, stimulus entrainment, and social relationships (Bevilacqua et al., 2019; Dikker et al., 2014; Zada et al., 2023; Hoehl et al., 2021). Research has further shown that turn-taking dynamics during verbal exchanges predict interpersonal neural coupling both in same-age and cross-age dyads (Pan et al., 2020; Nguyen, Schleihauf et al., 2021), highlighting the importance of not only studying dynamic interactions, but also of examining coupling dynamics within such interactions. Critically, even though many hyperscanning studies involve some form of verbal communication (Czeszumski et al., 2021), such conversation-internal factors are often ignored.

While Fig. 1 summarizes patterns that are observed across brain imaging modalities, in what follows we will focus on neurophysiological signatures, in particular those captured with electroencephalography (EEG).

Age-related neurobehavioral changes may affect many of these predictors of inter-brain coupling (and, consequently, socio-communicative outcomes). However, while socio-behavioral and stimulus-related predictors of inter-brain coupling are fairly widely studied, it is less well understood how general patterns in intrinsic neural features may predict interpersonal coupling in socially meaningful ways in non-clinical populations. Take "neural architecture:" Both healthy development and aging are marked by widespread changes in brain systems. These changes impact cognitive functioning (Cabeza et al., 2016; Paus, 2005; Casey et al., 2005; Hoff, 2006) and (the timing of) behavior. This raises the possibility that age-related differences in neural processing may disrupt communication and feelings of social connectedness, with tangible real-world implications (Dikker et al., 2022).

Some of these age-related similarities and dissimilarities in both brain and behavior raise the intriguing hypothesis that inter-brain coupling may be higher between children and their grandparents than between children and their parents. For example, children and older adults both show lower peak frequencies in their alpha oscillations compared to young adults (Tröndle et al., 2021; Miskovic et al., 2015; Mierau et al., 2017), less predictive preactivation in their neural signatures during language comprehension (Wlotko et al., 2012; Hahne et al., 2004), and slower speech rates on average (Martins et al., 2007; Skoog Waller et al., 2015).

Critically, not all age-related similarities between children and older adults are expected to lead to higher inter-brain coupling: Some neural

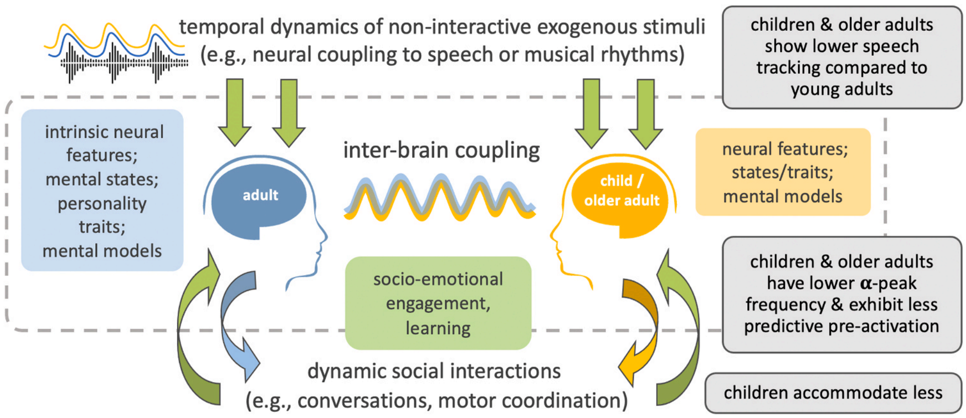

Fig. 1. A summary of predictors of inter-brain coupling during social interaction indyadic interaction (adapted from Dikker et al., 2021). External non-socialstimuli (top) and social behavior (bottom) provide exogenous sources of sharedstimulus entrainment and interpersonal social coordination, respectively,leading to similar brain responses, i.e., inter-brain coupling. Such couplingis mediated by intrapersonal (endogenous) factors ('intrinsic neuralfeatures'), including individual variation in (e.g., baseline oscillatoryfrequencies, etc.), mental states (e.g., focus and mood), personality traits(e.g., affective empathy), and priors (e.g., life experience and context-basedexpectations). Some of these are driven by age-based individual differences,and may thus affect coupling between (young) adults, children, and older adults(e.g., child-parent-grandparent interactions). For example, as discussed in themain text, both children and older adults show reduced brain-to-speech track-ingcompared to young adults, they have lower alpha peak frequency (neuralarchitecture), and exhibit less predictive processing. Adults and older adultscan accommodate their processing states during social interactions, but children are likely less able to do so.

signatures may instead be more disruptive to child-grandparent than to child-parent inter-brain coupling. For example, both children and older adults show less verbal fluency during language production (Harnsberger et al., 2008; Skoog Waller et al., 2015; Martins et al., 2007; Singh et al., 2007), less coherent discourse (Wright et al., 2014), and less precise or delayed event-related brain potentials (ERPs) to words during language comprehension (Anderson et al., 2012; Federmeier et al., 2003; Hahne et al., 2004; Atchley et al., 2006; Holcomb et al., 1992).

These changes can be partly attributed to the fact that children are still learning to effectively deploy cognitive control mechanisms to maintain, select, or revise incoming information, while healthy aging similarly impacts this ability on the other end of the human life cycle (Lee and Federmeier, 2011; Stites et al., 2013; Stine-Morrow et al., 2006). As a consequence, both children and older adults differ from young adults in how effectively their brains track speech ("entrainment"; Lakatos et al., 2008; Decruy et al., 2019; Zion Golumbic et al., 2013; Molinaro et al., 2021; Peelle et al., 2013; Peelle and Davis, 2012), use context information (Payne and Federmeier, 2018; Wlotko and Federmeier, 2012), and adjust activation states over time (Kutas and Iragui, 1998; Jongman and Federmeier, 2022). Notably, both older adults and children often fail to show processing patterns associated with the use of predictive preactivation. Our work and that of others has shown that young adults preactivate information about likely upcoming words (Dikker and Pylkkänen, 2013; Nieuwland et al., 2020; Van Berkum et al., 2005). Behaviorally, such predictive preactivation has been shown to be beneficial in that it increases information retention (Hubbard et al., 2019; Federmeier, 2007; Rommers and Federmeier, 2018a, b). Children exhibit predictive processing at an early age (Rabagliati et al.., 2016; Gambi et al., 2018) but they do not show the same memory benefits as adults do, and their neural patterns are not yet adult-like (Gambi et al., 2021; Benau et al., 2011). Findings from older adults, in turn, suggest that they resort less to predictive processing than young adults (DeLong et al., 2012; Federmeier et al., 2002; Wlotko et al., 2012).

Finally, let us consider scenarios where children and grandparents may dissociate from one another because the grandparent, but not the child, is able to adapt their neurobehavioral processes online. In cross-generational contexts, family members and strangers alike are known to adapt their language to support mutual comprehension, both toward children (e.g., "motherese"; Gleitman et al., 1984) and elders (Samuelsson et al., 2013). Accommodation is not unique to language production: Listeners are also able to adjust their processing strategies, including prediction (Fischer-Baum et al., 2014; Wlotko and Federmeier 2015; Brothers et al., 2017). Critically, such adaptive processing strategies will have to be at the disposal of the user: while very young children already engage in some forms of accommodation, they are unlikely to be able to adopt comprehension strategies that they have yet to acquire, like predictive preactivation. Older adults, in contrast, are able to (re)adopt predictive processing strategies (DeLong et al., 2012), though it is unknown if these findings extend to naturalistic communication. Thus, while both parents and grandparents may, for example, expect the speech of children to be less predictable and thus predict less, children are unlikely to adopt predictive preactivation strategies when talking to their parents since this system is not yet fully developed.

In sum, neurobiological and behavioral differences and similarities between children, parents, and grandparents may lead to either an increase or decrease in inter-brain coupling and, subsequently, socio-emotional and cognitive outcomes. There is little to no empirical data that directly speak to these hypotheses. While a rapidly growing number of studies investigate child-parent interactions (see Wass et al., 2020 for review), child-grandparent interactions are un(der)studied. The same is true for interactions between young and older adults. We did discuss some preliminary data in (Dikker et al., 2022) pertaining to inter-brain coupling from naturalistic dyadic interactions in adult populations, showing that on average the alpha peak frequency for inter-brain coupling was lower – and effect sizes smaller – for a participant pool consisting of dyads from a wide age range than for a sample comprising of mostly young adult dyads (Dikker et al., 2021b). But here again, systematic empirical studies on age-related effects on interpersonal coupling are lacking, let alone beyond dyadic contexts (Reinero et al., 2021; Dikker et al., 2017; Tissot et al., 2015; Dale et al., 2020; Gordon and Feldman, 2008).

We employed multi-brain neurocomputational models to simulate how widespread changes in brain systems that support cognitive functioning in both development and healthy aging affect multigenerational inter-brain coupling at the neurophysiological level. While, as illustrated in Fig. 1, a range of possible factors may interact to impact inter-brain coupling and socio-communicative outcomes, for the present simulations we limited ourselves to a small set of model parameters: we focus on age-related alpha peak frequency changes, and on dyadic vs. triadic interactions - remaining agnostic with respect to the nature and quality of the interaction or the social relationship between the actors.

A critical advantage of simulations is their ability to provide control over factors that are not easily available in empirical experiments but also to measure how different sources of variance impact the measures (Moreau and Dumas, 2021). Simulations can also easily probe the relationship between biological, behavioral, and social levels of the computational models, better identifying multiscale phenomena and mechanisms (Dumas and Fairhurst, 2021). Some simulation work in recent years has explored how intrinsic differences in neural rhythms and hemodynamic response functions between young children and their parents are expected to affect inter-brain coupling (Morimoto and Minagawa, 2022; Marriott Haresign et al., 2021), but to our knowledge no prior work has simulated trigenerational inter-brain coupling, neither in dyadic nor triadic scenarios.

3. Simulating child-parent-grandparent alignment

We utilized the Kuramoto model (Kuramoto, 1975) to simulate EEG hyperscanning recordings of social interactions. This model consists of non-linearly coupled oscillators, which here represent the brain oscillations of individuals engaged in social exchanges. Previous studies have also employed this model to simulate inter-brain coupling during dyadic interactions (Dumas et al., 2012; Heggli et al., 2019) as well as group coordination dynamics at the behavioral level (Zhang et al., 2018). Here, the oscillators in the model will simulate rhythmic brain activity in individuals. The coupling between them is intended to simulate sensorimotor coupling mediated by perception-action loops during face-to-face verbal communication (see Fig. 1 in Dumas 2011). The dynamics of the oscillators are given by the following equation:

$$\dot{\theta}_i = \omega_i + \sum_{j=1}^{N} c_{i,j}\sin\left(\theta_j - \theta_i\right)$$

where $\theta_i$is the phase of the ith oscillator, ω_i is the natural frequency of the ith oscillator, $c_{i,j}$ is the coupling between the ith and the jth oscillator, and N is the number of oscillators. For our simulations, we used $N = 2$ and $N = 3$ for dyadic and triadic social exchanges respectively, with the latter allowing us to simulate multi-generational interactions involving a child, a parent, *and* a grandparent. For each simulation, the natural frequencies of the oscillators were chosen randomly from a normal distribution with unit variance and centered on 12 Hz (parent, age ~35), 8 Hz (grandparent, age ~70), and 7 Hz (child, age ~5–6) respectively. These frequencies are based on general patterns observed in age-related alpha-peak frequency changes (Freschl et al., 2022; Scally et al., 2018). The coupling between the oscillators is given by a connectivity matrix C. In the triadic case scenario:

For each scenario, we ran 2000 simulations with a duration of $T = 60\ s$ and a time step of $\Delta t = 0.01\ s$. The initial phases of the oscillators were chosen randomly from a uniform distribution between 0 and 2π. All the code of the simulations has been made available on GitHub (github.com/ppsp-team/Hyper-Aging). We first simulated hyperscanning recordings of social interactions pertaining to parent-child dyads, parent-grandparent dyads, and grandparent-child dyads, respectively. Fig. 2A shows that inter-brain coupling - measured with the phase locking value (Lachaux et al., 1999) - was higher for grandparent-child interactions than for parent-child interactions (Cohen d = 0.33). We then proceeded to model inter-brain coupling in triadic multigenerational interactions, i.e., including the child, parent, and grandparent simultaneously. As control conditions, we ran the same simulations with within-generational dyadic and triadic scenarios (i.e., two or three adults; two or three older adults; and two or three children). The natural frequencies and the couplings were chosen in accordance with those used in the cross-generational scenarios. Fig. 2B shows how overall, the highest coupling is achieved between the grandparent and

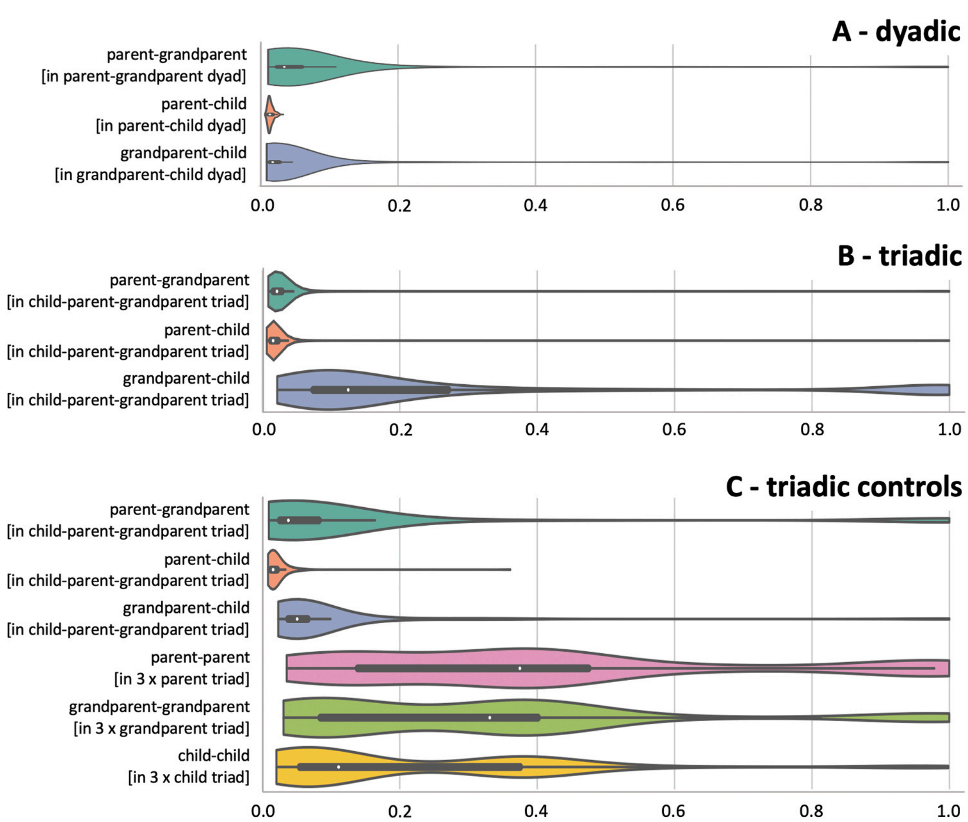

Fig. 2. Simulated inter-brain coupling during cross-generational interactions in dyadic (A) and triadic (B) scenarios show that coupling between grandparent and child is always higher than the coupling between parent and child, and that this effect is boosted by the presence of a parent (triadic simulations; 2B). Panel C displays simulations from two control experiments: The top three plots show that adjusting the alpha frequency so the grandparent and parent are more similar attenuates grandparent-child coupling; the bottom three plots show unigenerational triadic scenarios, showing that child-child synchrony is lowest overall.

the child, despite both exhibiting poor coupling with the parent (vs. Parent-Child: Cohen d=1.13).

One possible explanation could lie in that the model assumes that the grandparent and the child have a more similar natural frequency, which allows them to synchronize more easily. To challenge this hypothesis, we also conducted simulations with the same coupling matrix but with the natural frequencies of the oscillators chosen randomly from a normal distribution with unit variance and respectively centered on 12 Hz (parent), 10 Hz (grandparent), and 7 Hz (child). Thus, while the grandparent still exhibits a lower alpha frequency, it is more similar to the parent's than to the child's. As can be seen in Fig. 2**C**, now grandparent-child coupling is much weaker now than in the previous simulation. However, coupling still remains higher when compared to adult-child coupling (Cohen d=0.65), or parent-grandparent coupling (Cohen d=0.24).

$$C = \begin{pmatrix} 0 & 0.9 & 0.9 \\ 0.7 & 0 & 0.7 \\ 0.5 & 0.5 & 0 \end{pmatrix}$$

Together, as expected, these simulations demonstrate that the similarity of alpha frequencies may drive the stronger coupling between grandparents and children, when compared to parents and children. Critically, and perhaps somewhat surprisingly, this effect is amplified in a triadic context, with the parent seemingly acting as a catalyst for the coupling between the grandparent and the child. This illustrates how coupling in dynamic interactions is a byproduct of similarity and communication, with both phenomena being interdependent and mutually constraining, like M.C. Escher's Drawing Hands (Dumas and Fairhurst, 2021). While similarity can facilitate reciprocal alignment and communication, behavioral similarity is also made possible through the exchange of information.

4. From simulations to the real world

Studying caregiver-child interactions not only between children and parents (or young adult caregivers), but also between children and grandparents (or older adult caregivers) is a critical missing piece in our understanding of the neurobiological basis of family communication and relationships. The simulations presented here underscore this: our findings suggest that grandparent-child interactions may be more in sync than parent-child interactions under certain conditions. Critically, this enhancement of inter-brain coupling for grandparent-child interactions is more pronounced in *tri*-generational interactions that also include a parent. While the exact relationship between inter-brain coupling and socio-communicative outcomes is yet to be established, this possible benefit of tri-generational interactions as opposed to bi-generational interactions raises potentially valuable hypotheses pertaining to neurobiological contributors to findings showing that grandparent involvement in childrearing is most beneficial if both the grandparent and the parent are active household members (as opposed to grandparent-only households; Cruise and O'Reilly, 2014; Deindl and Tieben, 2017; Li and Liu, 2020; Perry, 2017; Pong and Chen, 2010; Reynolds et al., 2018). In other words: our findings underscore that a more nuanced understanding of the neurobiological basis of cross-generational interactions is vital, and that such knowledge can potentially be helpful in guiding interventions and social policies that consider the whole family.

While an increasing number of researchers have begun investigating naturalistic communication between parents and their children (e.g., Ocular et al., 2022), few, if any, have touched upon grandparent-child interactions. For example, one area of particular benefit would be within the domain of language. Relative to younger adults, older adults may use more complex grammar or speak more slowly, which could facilitate language acquisition by the child (Griffin and Spieler, 2006). Children, young adults, and older adults activate information with different latencies and even neural systems, which may yield a basic misalignment of their processing states. Since (dis)similarities in neural rhythms and processing have been linked to comprehension and socio-emotional outcomes (Dikker et al., 2021; Pan et al., 2020; Chen et al., 2022), this raises fundamental questions about the neurobiology of intergenerational communication, including the impact of such (mis) alignment on naturalistic cross-generational communication, the ability of intergenerational dyads to detect and overcome misalignment, as well as the potential for leveraging positive alignment amongst the dyad.

One possible reason why grandparent-child interactions are understudied may be sociocultural in nature; there is an overemphasis in the current literature on White, affluent families, and this may be driven by the overrepresentation of White, affluent scientists within the field (Sears, 1986; van Marum, 2020; Henrich, Heine, and Norenzayan, 2010; Kozlowski et al., 2022). This homogeneity severely limits our understanding of neural processes and constrains our knowledge of what we believe to be "normative" within developmental trajectories of cognition and behavior (Nketia et al., 2021). But the scientific community cannot automatically expect individuals from diverse socio-demographic backgrounds, often living in disinvested communities, to be motivated to participate in research without significant community partnership and engagement. Work in other fields has shown that research questions that contribute to scientific progress and help inform public policy can be generated by the public (Charles et al., 2020). However, community-based participatory research design approaches (Leavy, 2017) are rarely incorporated into neuroscience research. In our experience, partnerships with non-academic organizations are critical in facilitating such approaches (Dikker et al., 2019; Chen et al., 2022; Chen et al., 2021; Dikker et al., 2021a; Matuk et al., 2021; Dikker et al., 2017; Bevilacqua et al., 2019; Dikker et al., 2021b; Davidesco et al., 2021). Reducing obstacles to research participation also involves meeting families where they are at. Schools, museums, theaters, and community centers are natural gathering places, removing logistical barriers for community members to take part in research, and treating participants as 'citizen scientists' in the inquiry process makes them more motivated and invested. In addition to ensuring feasibility and data integrity, participatory citizen science has been shown to empower the public to identify and address issues that are both personally and socially meaningful (Eitzel et al., 2017).

One such issue is childcare: The current childcare crisis in the U.S. underscores the importance of examining child outcomes related to non-parental childcare. Although the literature has often found that, compared to children primarily cared for by their mothers, children who attend high quality non-parental childcare demonstrate gains in language and cognitive skills (Bradley and Vandell 2007; Burger, 2010; Dearing et al., 2018), but grandparent care may be an exception. For example, (Hansen and Hawkes, 2009) found that nine-month-olds in grandparent care had more vocabulary at age 3 compared to age-matched peers who attended center-based care during infancy. A recent study in Chile used propensity score models to compare children within maternal child care, center-based child care, and grandparent care (Narea et al., 2020) with results indicating that compared to maternal care, children in grandparent care and center-based care had higher cognitive, language, and motor scores (Narea et al., 2020).

Overall, investigating the neurobiological basis of multi-generational interactions may have broader impacts that could help improve family wellbeing and increase representation of families whose caregiving structures and family compositions are often excluded from mainstream (i.e., White, Western-centric) research and policies. With greater life expectancy, the duration of grandparenthood is increasing (Chamie, 2018) and grandparents as childcare providers could be an important form of intergenerational family support. Where state-provided services are less generous, the proportion of grandparents who provide regular childcare is greater (United Nations Publications, 2019). Intensive grandparent care is more likely to occur for grandparents with fewer resources, and this may increase socio-economic inequalities across families. Grandparents are often not included in research and policy initiatives, despite the increasingly large role they play in day-to-day caregiving, and social policies, including tax breaks or subsidies, that afford grandparents more flexibility to participate in their grandchildren's caregiving are essential.

5. Conclusion

We highlight the neural basis of grandparent-child interactions as an understudied area of research, generating a critical gap in our understanding of how family interactions shape child development from a neurobiological perspective. We use multi-brain neurocomputational models to simulate cross-generational inter-brain coupling in both dyadic and triadic scenarios, which suggest that grandparent-child interactions may be more beneficial than parent-child interactions under certain conditions, especially in tri-generational interactions that include an active household parent. These findings underscore how important it is that developmental social neuroscience research accounts for the diverse range of child-caregiver relationships.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Acknowledgments

This work is supported by the following funding sources: NIMH #R01MH125870 & #R01MH126468 to NHB; NSF #1908482 to SD; CIFAR Azrieli Global Scholar Program to NHB & GD; Institute for Data Valorization (IVADO) Professor Startup & Operational Funds #CF00137433 to GD; Fonds de la Recherche en Santé du Québec (FRSQ) Junior 1 salary award #285289 to GD. The simulations were enabled in part by the computational support provided by Calcul Québec (www.calculquebec.ca) and the Digital Research Alliance of Canada (www.alliancecan.ca).

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