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Enhancing Assessment of *Social Motor Synchrony* Through Full-Body Interaction: A Novel Approach with OSMoSIS Tool

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ABSTRACT

UPDATED—April 17, 2024. This paper reports on work in progress to develop an assessment tool for *Social Motor Synchrony* (SMS) in children's interactions. Expanding upon the foundation provided by the OSMoSIS motor sonification tool, we have developed an innovative approach for measuring *SMS* with children. Our method aims to overcome challenges stemming from variations in research settings and objectives encountered in studying *SMS* within the context of full-body interaction. Current tools for investigating *SMS* have been conducted in fixed settings, often limiting the interacting individuals to a seated position. However, this is in stark contrast to interventions such as music therapy, where the emphasis is on full-body interactions, and the settings exhibit considerable diversity. In such contexts, unrestricted movement is recognised as a fundamental element contributing to the overall efficacy and authenticity of the therapeutic experience, making it important to preserve the inherent benefits of a naturalistic setting. The study described in this paper explores the utility of OSMoSIS as a tool for assessing *social motor synchrony* revealing intriguing differences when comparing OSMoSIS with the well-known MEA software. This study not only brings a fresh perspective to the evaluation of *social motor synchrony* but also offers unique insights that set it apart from existing tools.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; *Haptic devices*; User studies.

KEYWORDS

assessment tool, social motor synchrony, autism, HCI, Motion energy analysis, full-body interaction, evaluation, music therapy

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1 INTRODUCTION

Understanding *Social Motor Synchrony* (*SMS*) is crucial for comprehending human interaction dynamics [4, 18]. Previous studies [19] have explored *SMS* in the context of autism, providing insights into potential variations in social motor behaviors. In light of the growing emphasis on adopting more interactive approaches, numerous research findings highlight challenges related to *Social Motor Synchrony* – the coordination of movements in mutual exchange to foster synchronicity in the autistic population. For instance, in a rocking chair paradigm, autistic children exhibited a distinct lack of inclination to rock symmetrically with their caregivers when compared to typically developing children [18]. Similarly, other studies [5, 20], in their exploration of social motor synchronisation tasks involving the coordination of objects, bodies, and faces, discovered a correlation between motor synchronisation and the degree of autism characteristics.

The manner in which autistic individuals embody self-organisation stands as a fundamental aspect of their interaction with the physical and social environment. Therefore, disparities in perceiving, interacting, and responding to the rhythms of the world may have implications for accommodating diverse social preferences and interactional styles. [20]. Measurements of *Social Motor Synchrony* may be a valuable indicator of someone's attitude towards the interaction or their interaction partner. Previous research [4] has especially focused on assessing synchrony in the interaction between mother and infant, via manual annotation (e.g., coding events in video recordings [25]) and computational analysis (e.g., time-series analysis from videos or sensors data [1]). In this paper, we focus only on computational approaches because manual annotation, whilst accurate, is not scalable.

This paper addresses a gap in the research by introducing the OSMoSIS framework, a novel tool designed to assess *SMS* in diverse and naturalistic contexts of full-body interaction. By introducing the OSMoSIS framework and study design for its evaluation, this paper contributes to filling this gap and advancing research in the field of *SMS* and interactive technologies.

2 RELATED WORK

Understanding Social Motor Synchrony (*SMS*) in full-body interaction demands sophisticated systems for capturing and analysing

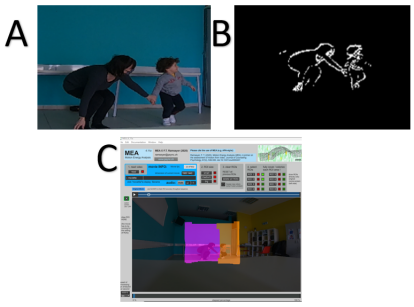


Figure 1: Example of Pixel differentiation

human movement nuances. Researchers have explored diverse technological approaches, from controlled lab setups to real-world scenarios [1, 6, 12]. This section outlines pioneering work in *SMS* assessment systems, spanning motion capture [12, 24], wearables [13, 16], and computer vision techniques [17, 23]. Computational tools generate multimodal movement data using video, wearables, or motion sensors [22, 24], and analytical tools assess synchrony within and between interacting groups [11]. Despite progress, studies on *SMS* in autism focus largely on stationary participants in controlled settings [2, 3], leaving a gap in exploring free-moving experimental contexts.

2.1 Motion Energy Analysis

Motion Energy Analysis (MEA) is a widely utilised tool for assessing *Social Motor Synchrony* (*SMS*) due to its cost-effectiveness and ease of use [6]. It employs a straightforward camera system to monitor movement, utilising automated video-image analysis to extract time-series data from recorded footage by scrutinising grayscale pixel patterns between frames [14].

However, employing the frame differencing method, as used in MEA, presents intricacies and constraints, particularly in assessing *SMS* within dynamic and uncontrolled settings like full-body interaction [8]. The high degree of movement variability inherent in such settings further complicates *SMS* detection and measurement [8].

2.2 Motion Capture and Its Role in Evaluating Social Motor Synchrony

Motion capture technology, exemplified by studies like Candidi et al. [15], has enhanced our grasp of *SMS* by enabling precise measurement of movement dynamics in social interactions. Wearable devices, such as those used by Tortelli and colleagues [21], have also contributed by quantifying motor coordination. In this study, we utilise Kinect for evaluating *SMS* during full-body interactions, providing a non-invasive and user-friendly solution for real-time data capture. Our analysis aims to deepen understanding of *SMS* in naturalistic settings. This underscores the role of motion capture in diversifying *SMS* research and advancing nuanced analyses of movement coordination. Subsequent sections detail our innovative use of Kinect and its implications for understanding social interaction dynamics.

3 OSMOSIS

The OSMoSIS (Observation of Social Motor Synchrony in an Interactive System) system, operates as an interactive system, translating children's movements into sounds that they can hear. It was first designed with the objective of unobtrusively enhancing children's perception of their body movements and providing bodily consistency by concurrently mapping body motion qualities to sounds [9]. OSMoSIS uses Microsoft Kinect for accurate body movement tracking. The system's name embodies its user-centric philosophy, emphasising the importance of observing and comprehending user behaviours and interactions within interactive systems. Its aim is to facilitate a gradual integration of methods for interaction, expression, and communication through sounds and body movements.

Additionally, the essential need for employing a non-obtrusive tool arises from the imperative to maintain the advantages inherent in a naturalistic setting, a consideration of particular significance when involving autistic participants. Many autistic individuals experience heightened sensory sensitivity, making it crucial to choose tools that are as unobtrusive as possible.

4 TECHNICAL DESCRIPTION

Following successful testing as a system beneficial for enhancing interaction in autistic children [8], OSMoSIS transitioned into an analytical tool for evaluating *SMS*. Utilising motion capture technology via Kinect, OSMoSIS introduces a more comprehensive approach, considering two distinct perspectives for assessing *SMS*, in contrast to MEA's frame differencing method. Specifically, it examines:

Position: This involves examining the correlation of body part positions by analysing the time series of user-defined coordinates.

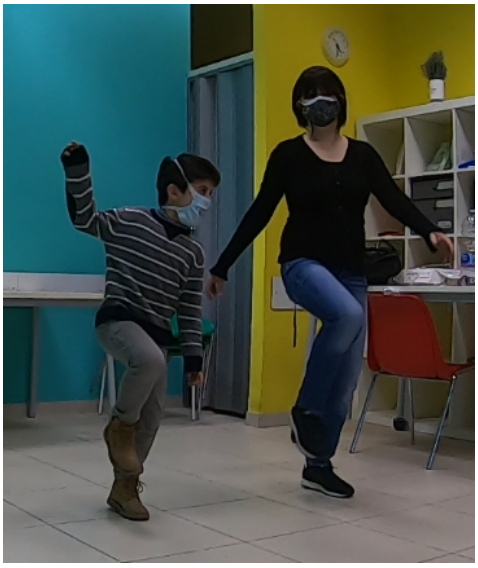
Energy: The energy is computed by examining how the energy levels of different body parts correlate with each other. These energy levels are derived from the time series of positions captured by the motion capture system. In essence, we analyse how the movements of different body parts relate to each other over time to calculate the overall energy expended during the activity

The technology consists of a laptop, a camera, Kinect, and Wi-Fi speakers present in a room (see Fig. 2a). To implement OSMoSIS, a robust technology stack was employed, leveraging JavaScript, AngularJS for the front end, Node.js for the back end, and MongoDB for data storage. Complementing this foundation, various third-party JavaScript plugins were integrated to augment the system's functionality and capabilities. The skills required by users of OSMoSIS are the same as those needed to use a mobile app and no technological education is needed.

4.1 OSMoSIS Methodology and Data Analysis

OSMoSIS calculates *SMS* between a facilitator and a child by cross-correlating their simultaneous movements. This involves averaging cross-correlations over 30-second windows with 10-second overlaps, applied consistently across sessions. The software also provides visualisations of correlation within each window. It produces two types of correlation coefficients: Position Correlation (PC), which measures the correlation between the x and y positions of the child and the facilitator, and Specific Kinetic Energy Correlation (SKEC), measuring correlation between derived energy-related

(a) OSMoSIS Setting



(b) Interacting dyad

Figure 2: Example of children interacting with the facilitator within the OSMoSIS setting

time series. PC is calculated directly from Kinect camera data capturing body movement, with each joint's position tracked every 1/15 seconds. Overall, OSMoSIS facilitates detailed analysis of *SMS* dynamics during interactions.

5 STUDY DESIGN

In this study, our goal was to explore the impact of sound synchrony, specifically motor sonification, on children's engagement with the adult facilitator, using the OSMoSIS analysis functionality alongside the established MEA analysis method to allow comparison. In the OSMoSIS system, the facilitator set four distinct sound options corresponding to specific movements to be performed and demonstrated to the child. These movements were associated with characteristic sounds, such as a drumbeat for marching or a harp sound for upper body movements. Once the facilitator presented each movement and its associated sound, the child was given the freedom to move or react as they wished.

During the interactive session, the volume of the sounds remained constant and did not vary based on the energy of the facilitator's or child's movements. Instead, the focus was on the facilitator's presentation of the movements and the subsequent child response.

After the predetermined time for each proposed movement elapsed, the facilitator changed the sound to introduce the next movement. In total, the facilitator changed the sound four times, corresponding to the presentation of the four different movements.

Following the interactive session, the children's movements were meticulously coded using Interact [10], a video observation tool. These movements were categorised as either independent, absent, or imitated for subsequent post hoc analysis. This approach allowed for a detailed examination of how children engaged with and responded to the presented movements and associated sounds, shedding light on the dynamics of interaction within the OSMoSIS framework.

Across the four sessions, the interacting users consisted of a child and a human facilitator modeling movements for the child. The human facilitator greeted the child warmly and proposed simple movements to encourage responses and enhance interaction. Four basic movements—arm movement, hopping, full-body movements, and jumping—were introduced by the facilitator, with each movement associated with a specific sound: harp, water flow, guitar, and drum.

Participants encountered two distinct conditions: the *randomised-sound* mode and the *model-based* sonification mode. In the *randomised-sound* setting, sounds were randomly generated, lacking coherence with children's movements, even when the child was stationary. Conversely, the *model-based* condition featured movements that aligned with the child's own movements.

To minimise potential order effects, the sequence of these sessions varied across all possible permutations for the 12 participants, ensuring a comprehensive exploration of the impact of sound conditions on children's engagement.

A Go Pro camera, inconspicuously positioned and often hidden from the child's view, recorded the entire session. However, occasional instances where the child moves out of the camera's view resulted in data loss, posing limitations for our subsequent evaluation, to be described in a future paper.

5.1 Preliminary results

This paper compares the methodologies of OSMoSIS and MEA in assessing *Social Motor Synchrony* (*SMS*). We conducted coding of interactions between the child and the facilitator using both MEA and OSMoSIS. The comparison of measurements between MEA and OSMoSIS revealed p-values of p=.68 for MEA and p=.59 for OSMoSIS in terms of position, indicating no statistically significant

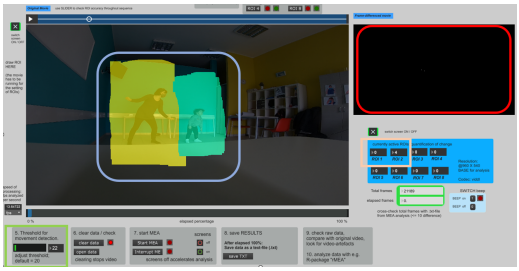


Figure 3: Example of misdetection from MEA where in the red square, in the top right side of the interface, we see that MEA was unable to detect the moving bodies of the facilitator and child. Indeed, within the orange box positioned below the red one on the right side, no movement was detected, denoted by an "O" for both the Regions of Interest (ROI) 1 - representing the child, and ROI 4 - representing the facilitator. The threshold, located in the lower left corner of the interface, was set to 22, for this session, a bit higher than the good threshold setting of 20. However, the sudden change of light did not allow the software to pick up the bodies.

difference. However, for energy measurements, OSMoSIS showed a statistically significant difference with a p-value of p=.05 compared to MEA. Here, we provide supporting reasons for these findings yet to be fully explored. While MEA employs pixel difference analysis, OSMoSIS utilises motion capture for detailed joint movement tracking. The comparison highlights differences in outcomes, emphasising the need for nuanced evaluation. For instance, MEA, in contrast to motion capture technology like OSMoSIS, overlooked instances of lower-level synchrony and missed certain synchronised movements (see Fig. 3) that fell below the established threshold setting of 20 (good) that determines the signal-to-noise ratio of the raw data [7].

This resulted in genuine instances of synchrony going undetected, and in some cases, non-synchrony was mistakenly identified as "false synchrony." MEA's pixel-based approach may overlook lower-level synchrony, whereas OSMoSIS offers precise detection and analysis of synchrony dynamics. OSMoSIS provides comprehensive spatial and energetic coordination analysis, surpassing MEA's limitations in movement detail assessment. While MEA offers accessibility, OSMoSIS ensures robust evaluation, overcoming pixel differentiation drawbacks for accurate movement analysis.

6 CONCLUSION

This work in progress paper introduces OSMoSIS, an innovative evaluation tool for studying *SMS* in full-body interaction, with a focus on autistic children. Utilising Kinect technology, we analysed participant positions and energies across four sessions involving *SMS* autistic children. Our study provides insights into assessing *SMS* and refining interventions. Moreover, by comparing OSMoSIS with the established method of MEA, we enhance our understanding of *SMS* in full-body interaction contexts. This comparison underscores the significance of our novel approach in quantifying *Social Motor Synchrony*.

7 FUTURE WORK

Future work should examine the usage of OSMoSIS as an evaluation tool in more depth, through a full analysis. Furthermore, by incorporating sophisticated technologies and metrics, we aim to capture a more detailed and nuanced understanding of *Social Motor Synchrony*, contributing to a more robust and accurate assessment of human interactions. This exploration aims to inform the design of interventions or tools, ensuring they align with diverse user needs and preferences. By providing valuable insights into enhancing *SMS* evaluation, these endeavors pave the way for future advancements in this domain.

8 SELECTION AND PARTICIPATION OF CHILDREN

Ethical approval for this study was granted by the University of Sussex Sciences & Technology Cross-Schools Research Ethics Committee. Twelve autistic children (9 boys, 3 girls) aged 5-11, were recruited from an Italian family-support group. Participants voluntarily enrolled, with informed consent obtained from their legal caregivers. Each participant attended four sessions, with the presence of another adult (e.g., parent, or caregiver) ensured throughout.

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