Multimodal perception in infants with and without risk for autism: A meta-analysis

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Abstract

This manuscript shortly introduces a methodological proposal regarding how human beings process multimodal information at early ages in life. It specifically examines to what extent different developmental scenarios may lead to different trajectories of this capacity. Infants at genetic risk for Autism Spectrum Disorder (sibs-ASD, from now on) are at higher risk than the general population for either presenting ASD or showing subclinical traits. Due, firstly, to the genetic liability of the disorder and, secondly, to available evidence showing multimodal processing impairments in diagnosed individuals at several ages, sibs-ASD seem to represent an atypical situation of development particularly interesting to track the course of the ability. Although there is a lack of evidence explicitly exploring it in that sample as well as in ASD on the whole, many recently published works use multimodal stimuli to test how sibs-ASD process social information. Here we propose a meta-analysis that, although it is still unconcluded, aims to reorganize indirect evidence and shed light not only on the early development of multimodal processing in siblings-ASD, but also on methodological and theoretical issues related to the study of this crucial human ability.

Index Terms: multimodal processing, infants at risk for ASD, meta-analysis.

1. What is multimodal processing?

Multimodal information is highly present in daily life perceptual experiences. Generally, it refers to events containing inputs from different sensorial modalities. Socio-communicative situations have been considered of special interest for being highly redundant contexts (Pons and Lewkowicz, 2014; Bahrick, 2012). A typical early interaction scenario with parents simultaneously smiling, staring and touching their infants exemplifies a situation where auditory, touch and visual inputs co-occur. Despite infants are exposed to complex information concerning several sensory systems at the same time, they do not perceive it separately; instead, they perceive multimodal information as a coherent and meaningful unitary event (Bahrick, 2004).

Infants are exposed to a complex input from birth and their cognitive systems become progressively expert in processing multimodal input throughout development rather than efficiently processing it from early on. Accordingly, some authors have claimed that specialization mechanisms, where experience plays a key role, are likely to be involved in the development of the ability to process multimodal events (Lewkowicz and Ghazanfar, 2009; see Pons, Lewkowicz, Soto-Faraco and Sebastián-Gallés, 2009), similar to that in unimodal processing (see, for instance, Pons and Bosch, 2010 for an example on speech domain and Pascalis, de Haan and Nelson, 2002 on faces).

Becoming specialized on those socially relevant inputs allows for the development of crucial human functions later on—i.e., the use of symbols, language and mentalization, or object and event perception— (Lewkowicz, 2014; Bahrick, Lickliter and Flom, 2004). Thus, exploring how multisensory perceptual develops would allow to better understand perceptual, cognitive, and social development. Notice that, while those many sensorial modalities are involved in social interactions, we only focus on studying audiovisual redundancy due to it is highly present in communicative contexts. Consequently, from now on, we will be referring to the audiovisual sensory combination when using ‘multimodal information processing’ (MMP).

2. Multimodal processing and developmental trajectories

Some theoretical approaches (such as Neuroconstructivism) have highlighted developmental trajectories as a methodological alternative to explore typical and atypical development, mainly because they allow to track the course of human abilities over time (Thomas, Annaz, Ansari, Scerif, Jarrold and Karmiloff-Smith, 2009). Considering that MMP 1) starts evolving in the first days of life but changes are supposed to continue beyond adulthood and 2) is a dynamic phenomenon that depends both on experience and increasing abilities of infants, it seems that running this type of analysis could allow to trace changes over time in MMP performance. By testing infants at different early ages it is possible to draw how this ability differentially evolves leading to specialization courses in the ability that may vary among infants. The model assumes that there are as many different possible performances for the same ability as individuals. MMP exemplifies this variability, since some authors have claimed that there are some atypical neurodevelopmental scenarios where the ability does not evolve successfully. Exploring alternative trajectories may lead to know deeper about the underlying mechanisms involved in MMP development.

3. Why does it interest to explore multimodal processing in atypically developing scenarios?

Based on clinical and research evidences, we suspect that ASD (Autism Spectrum Disorder) may be one atypically developing scenario of special interest to study the early development of MMP. ASD is a neurodevelopmental disorder of growing prevalence affecting near one percent of the population (CDC, 2007). From a clinical approach, it is defined by social communication impairments and restricted, repetitive patterns of behavior (American Psychiatric Association, 2013). However, affected individuals also show impairments in other abilities, such as Theory of Mind, executive function or central coherence, and unique processing styles which have been referred as the "cognitive phenotype of autism". It is now generally recognised that first-degree-relatives of affected individuals—mainly parents and siblings—are at increased risk for presenting sub-clinical forms of the clinical symptoms or the cognitive phenotype defining the condition, what is known as "broad autism phenotype" (Yirmiya and Ozonoff, 2007).

Particularly, infants who are siblings of older children with Autism Spectrum Disorder (siblings-ASD, from now onwards) present a heritable increased risk of developing the same disorder compared to the typical population, with a recurrence rate close to 19% (Ozonoff et al., 2011). Otherwise, they may show patterns of "broad autism phenotype" and milder impairments in abilities non-related with the core symptoms, which could lead them to differ from infants at low risk for autism in development (Yirmiya et al., 2006).

Some recent works suggest that MMP is impaired in individuals with autism at several ages—adults, adolescents and children— (Bebko, Weiss, Demark and Gomez, 2006; Massaro and Bosseler, 2003; Stevenson et al., 2014), although there is still no agreement on whether the lack of this ability could be considered as a characteristic of cognitive phenotype of ASD**.** Considering the genetic liability of the disorder along with these results showing that MMP is atypical in individuals with ASD at several ages, siblings-ASD may be an optimal sample to explore how this ability does develop in a non-normotypical scenario. Thus, when testing siblings-ASD in multimodal processing tasks it would be likely to expect that their developmental trajectories deviates from those followed by typically developing infants.

4. Evidence on multimodal processing in siblings-ASD

Some recent theoretical works have highlighted the interest of studying the development of MMP in atypical scenarios—and, especially ASD— (Bahrick, 2010; Bahrick and Todd, 2012; Hill, Crane and Bremner, 2012). Given the agreement on the need for exploring this phenomenon, we aimed to exhaustively search for evidence on the early development of the MMP in siblings-ASD. When doing a systematic search, a paradoxical result arose: although many studies explore social competence in siblings-ASD by using multimodal stimuli in tasks —probably due to that multimodal information is more salient in social interaction contexts—, there is still comparatively little published research on siblings-ASD, or even on ASD on the whole about this specific topic. In fact, we found a single work explicitly focused on the study of the ability itself in these groups (see Guiraud et al., 2012). That finding seems to point out that to date MMP has been only indirectly explored, which could partially explain the methodological heterogeneity found in aims, paradigms, methods and many other methodological issues, as well as the lack of direct unimodal and multimodal comparisons within a single experiment design. Making an effort to organize such heterogeneity may clarify firstly what variables could explain the results of previous (indirect) research on how siblings-ASD process multimodal information and, secondly, what variables (regarding participants, tasks, materials and other methodological aspects) could be more relevant to theoretically explain the process itself as well as the expected trajectories differences. But could these data be systemized?

5. Meta-analysis as an alternative to reorganise the study of multimodal processing in siblings-ASD

One tool seems particular suitable for that aim. Meta-analysis is a quantitative procedure that arose as an alternative of narrative and systematic reviews. It came out as a step beyond those two owing to it allows describing, integrating and analysing empirical data of primary studies regarding a specific research topic.

Meta-analysis is commonly defined by (Botella and Gambara, 2002):

1) Being precise, since it requests information about specific questions.

2) Being able to measure numerically to what extent data support these questions.

3) Replicating, as any other researcher would repeat by following the same steps and finally obtain similar results.

Among the advantages that it offers, its main potential contribution to our aim is probably that it allows to define organisers not included in the data of the primary studies selected. In other words, despite the lack of results explicitly exploring the ability, measures on MMP from studies exploring social performing in siblings-ASD may be reorganized under a new theoretical analysis different from those supported by primary studies.

According to Botella and Gambara (2006), although meta-analysis do not necessarily follow a linear sequence of stages, the tasks involved in the procedure would follow a logical order starting from 1) defining the problem through operations and hypothesis; 2) doing the search; 3) categorising the studies; 4) transforming data to a common metric; and, finally, 5) analysing and 6) discussing them. The following sections describe steps that have been completed by the time we are writing this manuscript (that is, from 1 to 3).

5.1. Defining questions and variables

One of the first steps —and, possibly, one of the hardest when running a meta-analysis— is to outline relevant questions and the associated variables that may allow to explore them. Considering our aims, we drew the key questions shown in Table 1.

Table 1. *Questions and variables*

QUESTIONS	VARIABLES
1. *Do infants at risk for ASD show difficulties when processing social information?*	**V1:** Multimodal Processing Performance
2. *Are these impairments modulated by sensory modality?*	**V2:** Sensory modality
3. *What is the developmental pattern*	**V3:** Age

of this ability?	
4. *Do those impairments change with age depending on sensory modality?*	**V4:** Age x sensory modality

To answer the first question, it is necessary to extract from the studies 'the mean performance in tasks using multimodal stimuli' of infants at high and low risk for ASD, in order to empirically compare them as groups.

As it has been pointed out, there are no previous studies explicitly comparing the influence of sensory modality (unimodal *vs*. multimodal) in a complete experimental design. However, studies exploring social development in siblings-ASD use either unimodal or multimodal tasks. For that reason, we also decided to codify the modality of the stimuli used in the task of studies exploring social processing in order to indirectly test its possible influence in group differences (as question 2 indicates).

Questions 3 and 4 refer to whether impairments in social processing would change throughout development and, if they do, whether it varies depending on the uni or multimodal nature of stimuli.

5.2. Location of the studies

Meta-analysis requires a search strategy that needs to be developed with care. Once key questions and variables were defined, it was time to decide what keywords would be included. Doing the search mainly involves to enclose the main representative results arising from the questions and variables defined previously and, at the same time, to exclude papers that do not meet certain criteria. Regarding keywords, 'at risk' and 'siblings' as well as 'ASD' and 'autism' were finally selected (both as synonymous pairs) for representing the sample. A full search on PsycINFO and PsycARTICLES—frequently used databases in the concerned topic—was conducted in August 2015. We aimed to run a search as inclusive as possible by combining the following keywords and *Boolean* operators: ('high risk' OR 'siblings') AND ('autism' OR 'ASD'). In addition, results were restricted by age by entering only works that assessed infants, toddlers and children. Despite our search focused on measures on MMP from studies exploring social performing in siblings-ASD, we decided not restricting the search to studies exploring social performance because many works did not explicitly state that term as a keyword or in the abstract although they explored it (for instance, studies exploring processing of faces or speech). Finally, we indicated that duplicates were excluded from the final sample.

5.3. Inclusion criteria

By using all the restrictors mentioned we obtained a search containing 1199 studies that was narrowed down by the following inclusion criteria (summarized in Table 2) that filtered studies not fitting with our key questions: 1) The studies mainly focused on exploring social processing; 2) at least two groups of infants were tested (high and low genetic risk for ASD) ; 3) participants aged from 0 to 36 months old (that is, from birth to age of diagnosis); 4) the studies run experimental designs where conditions are carefully manipulated (remaining excluded, for instance, theoretical reviews or observational studies); 5) quantitative continuous measures were registered (namely, reaction or fixation times and latencies). Furthermore, only studies showing all the information needed for future calculation were incorporated (either descriptive or contrast statistics). Any study not meeting these criteria were excluded. The final selection included 47 academic journal articles as well as dissertations and posters. It is also worth noting that, among that sample, 18 were collected from secondary informal sources such as the references cited in the papers primarily found as well from the main research groups' websites (namely, BASIS Team, Autism Speaks and BSRC) as well as those of its members. In both cases, we aimed to avoid selecting biased results, a trend that is usually referred as 'publication bias'.

Table 2. *Exclusion criteria*

Domain	Social
Comparison groups	Risk for ASD (high and low)
Age	0-36 months
Design type	Experimental
Measures	Quantitative continuous

5.4. Coding of characteristics

After doing the search we defined moderator variables, that is, those considered more likely to play a role in the effect sizes arisen from the expected high-risk and low-risk between-groups' differences. Thus, our selection was newly restricted by questions and variables shown in Table 1. We report those considered relevant to our aims in Table 3.

The only relevant participant characteristic for our analysis was infants' 'Age'. We entered mean age in days for each group of participants, which may contribute to answer Questions 3 and 4 shown in Table 1 (*What is the developmental pattern of this ability?* and *Does those impairments change with age depending on sensory modality?*).

The remaining coded variables mostly involved features regarding stimulus, namely: 'type of modality', defined as a dichotomy between unimodal or multimodal depending on whether information shown in the task belong to one or more sensory modalities; 'sensory modality', that is, whether the stimuli used in the tasks contained neither auditory, visual nor audiovisual input); 'sensory dominance', which only refers to those tasks that include audiovisual multimodal with a predominance of either visual or auditory information; 'stimuli content', that refers to the nature of the information contained in the task, which goes from faces or objects to speech or non-speech sounds; and, finally, 'other stimuli features' (related to whether they are static or dynamic, simple or complex, etc.). We decided to codify those variables for being at the core of our main hypothesis claiming that sensory nature of the stimuli may influence on how siblings-ASD process social information (corresponding to Questions 1 and 2 in Table 1), which probably differs throughout development (as Question 3 points out), meaning that both type of variables (regarding the nature of the stimuli and age) presumably mutually interact (see Question 4).

We also coded detailed information regarding methodological issues, such as the dependent variables measured (for instance, fixation times, reaction times or latencies) as well as the instruments (whereas some studies use *eye-tracker* others record EEG) and methods used (such as habituation or head preference), since we hypothesize that they may play a role in the direction of between-groups differences. Finally, we decided to codify variables—such as year and author— that sometimes show unexpected results.

Table 3. *Variables codified (with some examples in brackets)*

Age (Mean group age, in days)
Type of modality (Unimodal/Multimodal)
Sensory dominance (Audio-visual/Visual-auditory)
Sensory modality (Auditory/Visual/Audiovisual)
Stimuli Content (Faces, sounds, speech, objects, etc.)
Other Stimuli Features (Static/Dynamic, Simple/Complex)
Instrument (*Eye-tracker*, EEG, HHP, NIRS, etc.)
Dependent Variable (Fixation time and %, amplitude and latencies, visual preference, reaction time, latencies etc.)
Paradigm (Habituation, head preference, EEG, NIRS. etc.)
Year
Author

6. Conclusions

Meta-analysis is a methodological tool that may help to reinterpret data more systematically by detecting the relationship between mediating variables, such as the possible role of sensory modality of stimuli and age, in how infants at higher risk for ASD process socially relevant information. Based on the progress made so far in our research, we believe that both the results and the process itself of this meta-analysis will allow us to identify cues that could be relevant not only on the early development of MMP in siblings-ASD, but also on methodological and theoretical issues related to the study of this crucial human ability.

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